Land-Use and Land-Cover Change from 1974-2008 around Mobile Bay, AL

Final Report
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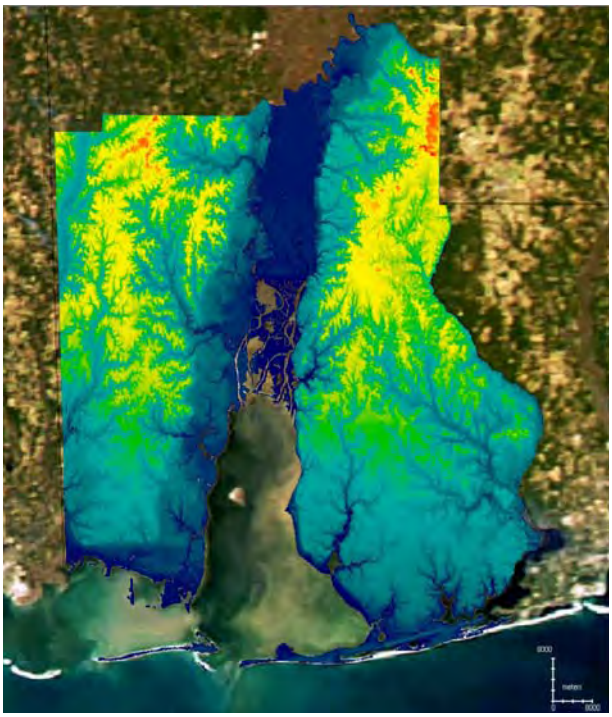


Digital elevation model (DEM) overlay of Mobile and Baldwin Counties draped onto a MODIS image. On the DEM, darker blues and reds indicate lower and higher elevations, respectively.

1. Executive Summary

This document summarizes the major findings of a Gulf of Mexico Application Pilot project led by NASA Stennis Space Center (SSC) in conjunction with a regional collaboration network of the Gulf of Mexico Alliance (GOMA). NASA researchers processed and analyzed multi-temporal Landsat data to assess land-use and land-cover (LULC) changes in the coastal counties of Mobile and Baldwin, AL between 1974 and 2008. Our goal was to create satellite-based LULC data products using methods that could be transferable to other coastal areas of concern within the Gulf of Mexico. The Mobile Bay National Estuary Program (MBNEP) is the primary end-user, however, several other state and local groups may benefit from the project's data products that will be available through NOAA-NCDDC's Regional Ecosystem Data Management program.

Mobile Bay is a critical ecologic and economic region in the Gulf of Mexico and to the entire country. Mobile Bay was designated as an estuary of "national significance" in 1996. This estuary receives the fourth largest freshwater inflow in the United States. It provides vital nursery habitat for commercially and recreationally important fish species. It has exceptional aquatic and terrestrial bio-diversity; however, its estuary health is influenced by changing LULC patterns, such as urbanization. Mobile and Baldwin counties have experienced a population growth of 1.1% and 20.5%, respectfully, from 2000-2006. Urban expansion and population growth is likely to accelerate with the construction and operation of the ThyssenKrupp steel mill in the northeast portion of Mobile County.

Land-use and land-cover change can negatively impact Gulf coast water quality and ecological resources. The conversion of forest to urban cover types impacts the carbon cycle and increases the freshwater and sediment in coastal waters. Increased freshwater runoff decreases salinity and increases the turbidity of coastal waters, thus impacting the growth potential of submerged aquatic vegetation (SAV), which is critical nursing ground for many Gulf fish species. A survey of Mobile Bay SAV showed widespread decreases since the 1940s. Prior to our project, coastal environmental managers in Baldwin and Mobile counties needed more understanding of the historical LULC, and therefore to properly assess the impacts of increasing urbanization. In particular, more information on the location and extent of changing urbanization LULC patterns was needed to aid LULC planning and to assess predictions of future LULC patterns. Our products will assist the coastal environmental managers and land-use planners make better LULC planning and implementation decisions. Our project also helped to establish a historical baseline of LULC distributions, which is a fundamental need in any stewardship plan.

The primary research objective of our project was to produce historic and current geospatial LULC change products. A multi-decadal coastal LULC change product was the major project deliverable. The geographic extent and nature of change was quantified and assessed for the upland herbaceous, barren, open water, urban, upland forest, woody wetland, and non-woody wetland-dominated land cover types. We focused on regional analyses of decadal-scale urban expansion and watershed-scaled analyses of LULC change for multiple areas of concern to the Mobile Bay NEP (Figure A). We used the following dates to derive LULC classification products from Landsat data: 1974, 1979, 1984, 1988, 1991, 1996, 2001, 2005, and 2008. We assessed the accuracy of our products using randomly sampled locations and digital geospatial reference data including field survey data, high resolution ortho-rectified aerial photography, high resolution multispectral and panchromatic satellite data displays (from QuickBird and Corona sensors), digital elevation model data, and National Wetlands Inventory wetland cover type data. NOAA's Coastal Change Assessment Program's (C-CAP) and National Land Cover Database (NLCD) products were used for qualitative comparison in assessing map accuracy. We calculated an average overall accuracy of 87% with similar overall accuracies for the older (MSS) and newer (TM and ETM) Landsat LULC products.

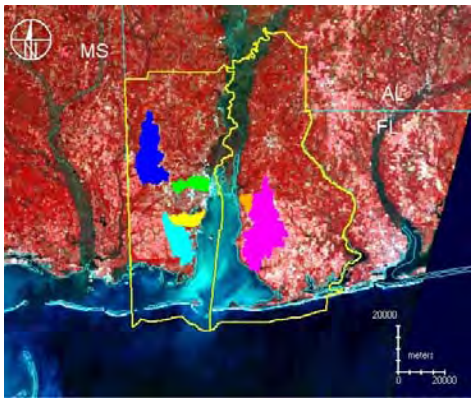


Figure A. Location map of study area. Yellow identifies the Mobile (left) and Baldwin (right) counties – the regional-scale area of study. The watershed-scale regions are shown in orange (D'Olive Bay), magenta (Fish River), green (Three Mile Creek), cyan (Fowl River), yellow (Dog River), and blue (Big Creek). State boundaries (cyan) are draped upon an AWiFS satellite image.

Figure B shows an example of the LULC products computed during the project. It shows LULC in 1974 (baseline, left) and in 2008 (right). We found a substantial LULC change over the 34-year study period. The most striking qualitative (visual) change is the urban expansion around the City of Mobile and along the Eastern Shore. In the northeast portion of the study area, some upland forest has changed to the upland herbaceous land cover type. The latter change is probably transitional, due to forest harvesting cycles.

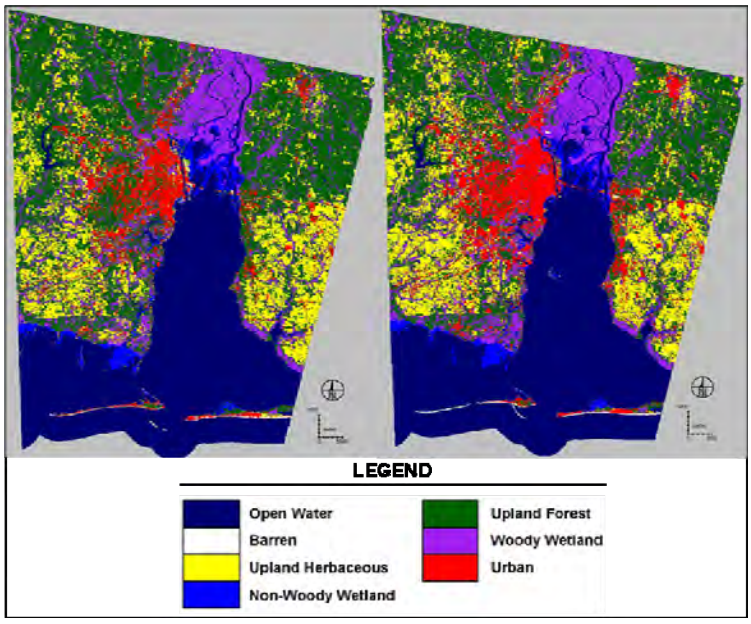
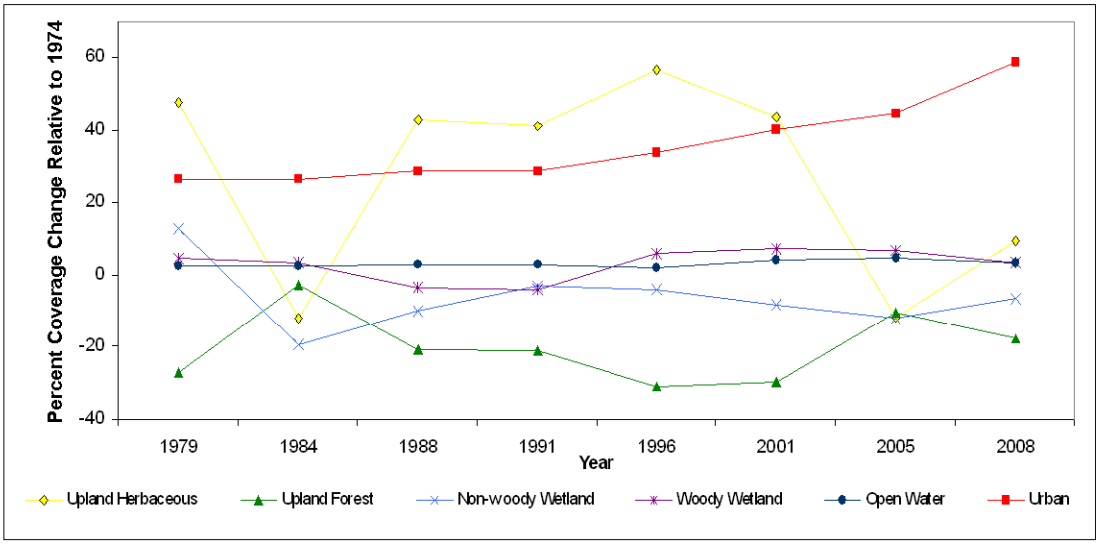


Figure B. Landsat-derived land-use and land-cover data product for 1974 (left) and 2008 (right) showing surveyed area within Mobile and Baldwin counties.

LULC change was normalized within each class to the baseline (1974; Figure C). Urban landscapes consistently increase through time and there is an approximate 30% increase in urban land-cover between 1974 and 1979, with that change increasing to almost 60% when considering the entire time series. There is noteworthy fluctuation amongst the upland herbaceous and upland forest landscapes. These data suggest a cyclical land swapping between upland herbaceous and upland forest landscape, however, our research is unable to make this conclusion definitely. The non-woody wetlands decreased over time (-6.4%, or ~2400 acres), while the woody wetlands slightly increased (+3.4%, or ~6500 acres).

Urban expansion in northern Mobile Bay is shown in Figure D. These satellite-based estimates indicate that during the 34-year study period urban areas increased from 80,972 to 128,662 acres, representing a 58.9% increase, or 1.73% per annum for both counties. The period between 1974 and 1984 shows the greatest expansion in the urban landscape (21428 acres, or 1.48%, Mobile and Baldwin counties), and the expansion was most dominant in the northern Mobile Bay region shown in Figure D.

Information from the project was immediately used for aiding Mobile Bay NEP LULC planning efforts. Results from the project were incorporated into the Mobile Bay NEP's State of the Bay report.



Class	Coverage (acres)								
	1974	1979	1984	1988	1991	1996	2001	2005	2008
Upland herbaceous	180295	265938	158592	257969	254973	282511	258913	159564	197118
Barren	2521	4058	4492	2672	4965	4709	7046	7731	5305
Upland forest	493301	359217	480289	390702	388236	340497	347224	442474	406703
Non-woody wetland	37475	42214	30139	33749	36321	36081	34430	32964	35080
Woody wetland	203704	213013	210440	196284	195727	215731	218139	217327	210192
Open water	450543	461839	462655	463506	464225	460829	469246	471609	465750
Urban	80972	102416	102400	104125	104338	108455	113815	117144	128664

Figure C. Percent coverage change relative to 1974 for each land-use and land-cover class (except barren) for Mobile and Baldwin counties. Tabular data show the Landsat-derived geospatial statistics for each land-use and land-cover class in acres. Barren was excluded from the figure because this land cover type comprises a small percent of the total coverage (<0.5%, is often transitional in nature, and its small acreage changes are not readily observed in relation to the other LULC categories.

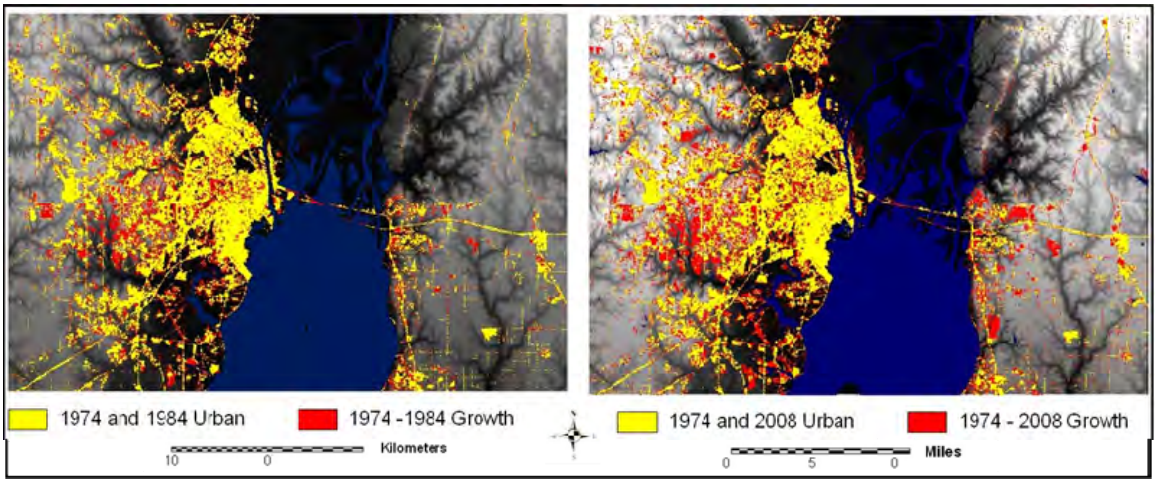


Figure D. Urbanization for the northern portion of Mobile Bay between 1974 and 1984 (left) and 1974 and 2008 (right). Yellow regions in both figures were urbanized in 1974. Red regions show the growth of urban regions from 1974 to 1984 (left) and 1974 to 2008 (right). The backdrop is a USGS DEM where dark grays designate lower elevations and lighter grays and white tones denote higher elevations.

2. Background

The purpose of this project was to quantify and assess geospatial land-use and land-cover (LULC) changes in the coastal counties of Mobile and Baldwin, AL. These two counties border Mobile Bay, which has the fourth largest freshwater inflow in the United States. The Mobile Bay estuary is economically vital to the nation in terms of shipping, fishing, and recreation. It is environmentally important in multiple ways, for example, it provides invaluable nursery habitat for commercially and recreationally important fish species. The region also has exceptional aquatic and terrestrial bio-diversity. The health of the estuary is influenced by changing land-use patterns, much of which has been attributed to urbanization since Hurricane Frederic in 1979. Mobile was designated as an estuary of "national significance" in 1996 (MBNEP, 2007). Mobile Bay has been identified by participants of the Gulf of Mexico Research Requirements Planning Workshop as an area of critical study. The Mobile Bay estuary was selected by NASA Stennis Space Center (SSC) and its partners as a region for investigation because of the observed anthropogenic changes and because of its environmental diversity and ecological importance. This work is supported by several Federal, state, and locally led research projects currently active in Mobile Bay, Grand Bay, Weeks Bay, and the Mississippi Sound.

3. Objectives

This project included several objectives. The initial objective was to survey the needs of the Mobile Bay coastal environmental managers to formulate a project topic. It was determined that NASA data and data products could assist Mobile Bay National Estuary Program (MBNEP) with validating land-cover and land-use changes identified through a separate MBNEP funded project with USGS, thus initiating this collaboration. The primary research objective was for NASA SSC to compute Landsat-based historic and current LULC change detection products for MBNEP that would be used as decision support tools for coastal resource planning and outreach and education for addressing coastal community LULC planning needs. Within this objective, we focused on decadal-scale urban expansion and 'areas of interest' (Figure 1), determined by MBNEP. The resulting digital and static products will be transferred to MBNEP and NOAA-NCDDC, one of NASA's Federal agency partners, for dissemination, further evaluation, and use. Throughout this project it was our goal to develop NASA-specific LULC data products for the Mobile Bay LULC planning community using methods that could be transferable to other coastal regions along the Gulf of Mexico. A third objective was to establish and maintain communication with and seek guidance from our federal and Mobile Bay coastal environmental manager partners.

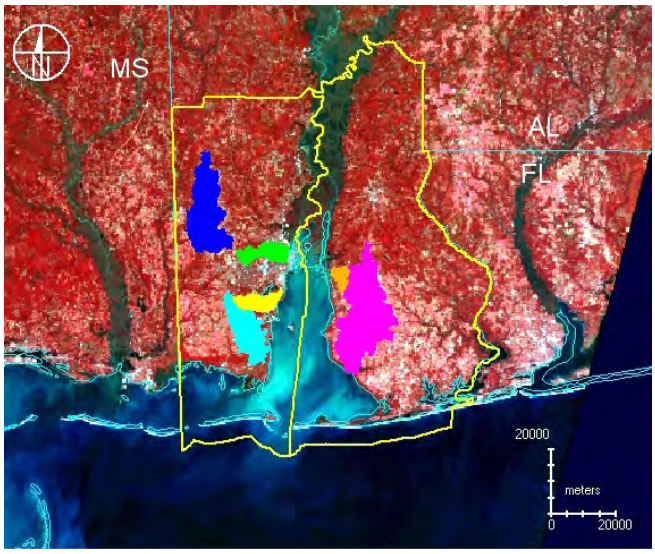


Figure 1. Location map of study area. Yellow identifies the Mobile (left) and Baldwin (right) counties – the regional-scale area of study. Areas of interest for study of watershed-scale processes are shown in orange (D'Olive Bay), magenta (Fish River), green (Three Mile Creek), cyan (Fowl River), yellow (Dog River), and blue (Big Creek Lake). State boundaries (cyan) are draped upon an AWiFS satellite image.

4. Primary Project End-User: Mobile Bay National Estuary Program

The Mobile Bay National Estuary Program was established in 1995 to "promote wise stewardship of the water quality characteristics and living resource base of the Mobile Bay estuarine system" (MBNEP, 2008b). Sponsored by the EPA and administrated through Dauphin Island Sea Lab, this program does not have regulatory power; however it is responsible for bringing together all facets of the Mobile Bay community (e.g., government, industry, academia, non-profits, and citizens) to help provide, protect, and conserve the Mobile Bay environment. Yearly goals and objectives of MBNEP are described in Comprehensive Conservation and Management Plan (CCMP) Work Plans with the most recent one published for FY2009.

MBNEP is currently active in approximately 50 coastal conservation projects throughout Mobile and Baldwin counties (MBNEP, 2008a). One issue of concern for the Mobile Bay region is the rapid increase of the human residential population, especially in Baldwin County, and its effect on the land and on coastal waters (U.S. Census Bureau, 2008). MBNEP has responded to these concerns by including these issues in their FY2009 Work Plan: "this project [the collaboration between MBNEP and NASA SSC] will be of inestimable value in helping us assess coastal change due to development and its impact on water quality, habitat, and living resources populations. It will also allow us to better educate our coastal communities about these impacts and options for future planning" (MBNEP, 2008a). The explicit mention of the working relationship between NASA SSC and MBNEP in the Work Plan identifies the value of this collaboration to the end-users.

5. Methods

5.1 LULC Product Generation

Target dates for NASA-generated LULC products for Mobile Bay (herein, MB-LULC) were determined using two criteria: 1) Correspondence with pre-existing federal agency land-use and land-cover classification products (National Wetlands Inventory, NWI; National Land Cover Database, NLCD; and Coastal Change Analysis Program, C-CAP); and 2) End-user's requirements. Figure 2 shows a timeline indicating the MB-LULC products, hurricanes that most significantly impacted the Mobile Bay region, and the major pre-existing, nationally sponsored, LULC products for this region.

Multiple scenes of Landsat data were acquired for generating single date LULC classifications across the entire scene of acquired data according to the dates shown in Figure 2: 1974, 1979, 1984, 1988, 1991, 1996, 2001, 2005 (pre-Katrina), and 2008 (Table 1). The study area was located within path 21 and row 39 for the WRS-2 system that is used with most Landsat data. For the Landsat MSS (Multispectral Scanner) data, the WRS-1 system was used and our study region was found within path 22 and row 39. Landsat MSS data was acquired for three dates, Landsat TM (Thematic Mapper) for five dates, and Landsat ETM (Enhanced Thematic Mapper) for one date (Table 1). The MSS data used in subsequent classification consisted of four bands, including one green band and red band and 2 NIR (near infrared) bands. The TM and ETM data used in classification consisted of blue, green, red, NIR (near infrared), and 2 SWIR (short wavelength infrared) bands. The thermal band of Landsat TM and ETM data was not utilized, due to its lower spatial resolution.

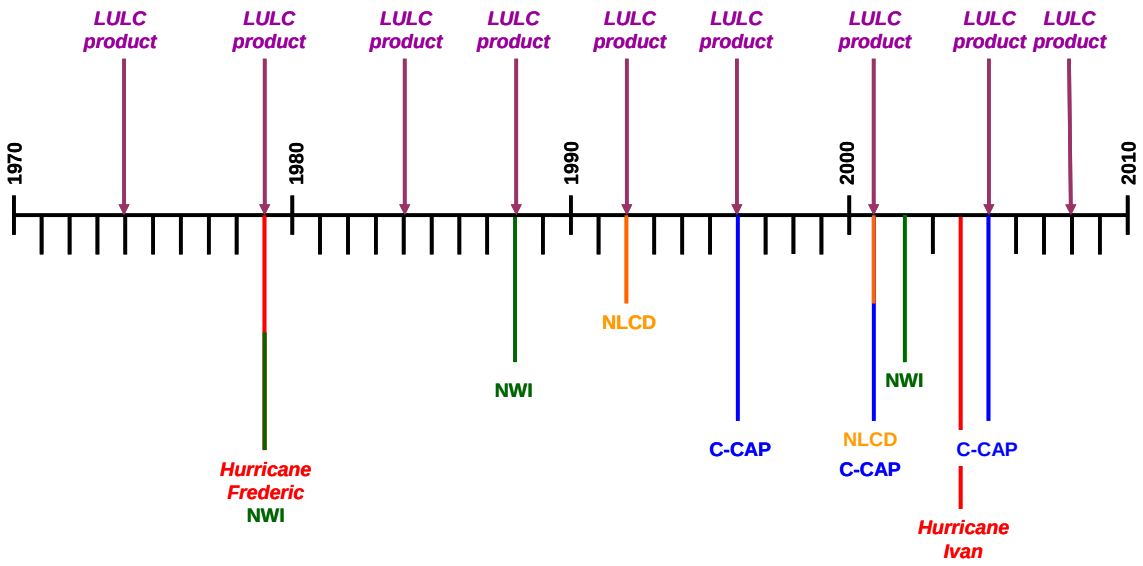


Figure 2. Temporal distribution of nine land-use land-cover (LULC) NASA SSC products that were produced based on Landsat. Timeline also shows the dates when other LULC classification schemes to identify either wetland or upland change have been published: National Wetlands Inventory (NWI), National Land Cover Database (NLCD), and Coastal Change Analysis Program (C-CAP).

Table 1. Landsat data used for LULC classifications.

Year	Sensor / Resolution	Path	Row	Collection Date
1974	Landsat MSS / 60m	22	39	11/12/1974
1979	Landsat MSS / 60m	22	39	10/26/1979
1984	Landsat MSS / 60m	21	39	09/06/1984
1988	Landsat TM / 30m	21	39	02/22/1988
1991	Landsat TM / 30m	21	39	09/26/1991
1996	Landsat TM / 30m	21	39	01/27/1996
2001	Landsat ETM / 30m	21	39	03/05/2001
2005	Landsat TM / 30m	21	39	03/24/2005
2008	Landsat TM / 30m	21	39	03/16/2008

The nine Landsat scenes were co-registered to a "master" ortho-rectified Landsat scene acquired 26 September 1991. The ortho-rectified scene data set was produced and acquired through the NASA Scientific Data Purchase program. Geo-corrected Landsat data was rescaled to planetary reflectance for computing NDVI (Normalized Difference Vegetation Index) data products. The latter were occasionally used as collateral data in evaluating and refining the LULC products. Geo-corrected raw data were utilized as the primary data source for producing our LULC products.

Each LULC product was primarily based upon classification of one date of Landsat data using ERDAS Imagine for image processing and analysis. Classification was performed using a hybrid unsupervised/supervised approach. Initially, a given Landsat data set was subjected to unsupervised classification using ISODATA clustering with 20 total clusters, convergence set to 0.995 (on scale of 0 to 1), 100 iterations, and cluster means initialization along the principal axis. A description of the ISODATA algorithm described further in the ERDAS Field Guide (Leica Geosystems, 2005). The resulting classification was then recoded into water, forest-dominated land, and non-forest dominated land. This "first cut" classification was used to isolate raw data into two subsets of forest-dominated and non-forest dominated raw data, respectively. The two raw data subsets were subjected to unsupervised

classification, clustering to 16 classes for the forest-dominated raw data and 20 cluster classes for the non-forested raw data. These cluster classes of the aforementioned classifications were described with respect to the LULC scheme. Some clusters pertained to multiple LULC categories. The raster attribute table for each classification was edited to include an attribute column for each LULC category. Table 2 shows the MB-LULC classes in relation to the C-CAP classification scheme. On a per-cluster class basis, we assigned a value of one to the attribute column for each LULC class when the cluster included that LULC category and we assigned a value of zero for each LULC class when the cluster class did not pertain to a given LULC class.

Spatial models were constructed to produce binary masks of each targeted LULC class. C-CAP products were used to reduce classification confusion within certain targeted classes; in particular, urban, woody wetlands, and non-woody wetlands. C-CAP LULC data products for 1996, 2001, and 2005 (pre-Hurricane Katrina) were recoded into the same seven classes as used in the aforementioned Landsat classifications. Images showing the maximum extent of urban, woody wetlands, and non-woody wetland LULC categories were computed from the union of the 1996, 2001, and 2005 extent of each applicable category. These masks were not completely mutually exclusive; additional editing was performed using a maximum value compositing approach to compute a discrete, thematic wall-to-wall refined classification.

Table 2: Comparison of land-use and land-cover classifications employed by NOAA C-CAP's program and our Mobile Bay (MB) LULC project.

C-CAP LULC Class	Corresponding MB LULC Class	C-CAP LULC Class	Corresponding MB LULC Class
Uplands	***Uplands***	***Wetlands***	***Wetlands***
Developed, high intensity	Urban	Palustrine forested wetland	Woody Wetland
Developed, medium intensity	Urban	Palustrine scrub/shrub wetland	Woody Wetland
Developed, low intensity	Urban	Palustrine emergent wetland	Non-Woody Wetland
Developed, open space	Urban	Estuarine forested wetland	Woody Wetland
Cultivated crops	Upland Herbaceous	Estuarine scrub shrub wetland	Woody Wetland
Pasture/hay	Upland Herbaceous	Estuarine emergent wetland	Non-Woody Wetland
Grassland/herbaceous	Upland Herbaceous	Tundra	
Sedge/herbaceous		Perennial Ice/snow	
Deciduous forest	Upland Woods	Moss	
Evergreen forest	Upland Woods	***Other***	***Other***
Mixed forest	Upland Woods	Water	Open Water
Scrub/Shrub	Upland Woods	Unconsolidated shore	Open Water
Dwarf scrub		Palustrine aquatic bed	Open Water
Barren land	Barren	Estuarine aquatic bed	Open Water

A spatial model was implemented to merge the individual classifications of LULC classes into a wall-to-wall product. This model used a maximum value compositing technique in which certain LULC categories were weighted higher in order to reduce classification confusion – the weighting is given in Table 3. If needed, additional classification refinement was completed to reduce visible classification error. Such refinement usually was completed by reclassification of an identified problematic class, generally using raw data masking and cluster busting techniques described by Jensen (1996). Summary area tables were produced for each LULC classification (one for each targeted date). The classification products were also subset to derive additional products for watershed areas of interest (Figure 2). LULC classification summary statistics were computed for the following watersheds of interest: D'Olive Bay,

Three Mile Creek, Upper Fish River, Dog River, Fowl River, and Big Creek Lake. A subset of the study area in northern Mobile Bay was selected and utilized for demonstration purposes.

Table 3. Weighting values used during data processing for our Mobile Bay (MB) LULC products.

MB LULC Category	Weighting
Open Water	10
Barren	20
Upland Herbaceous	30
Non-Woody Wetland	40
Upland Forest	50
Woody Wetland	60
Urban	70

5.2 LULC Change Detection

LULC change detection products were generated using standard GIS overlay analysis techniques. Our change detection approach involves comparison of two dates of LULC classifications. The LULC categories of the first date were recoded into values of 10, 20, 30, 40, 60, and 70, and the LULC categories of the end date retained the original class values of 1, 2, 3, 4, 5, 6, and 7. An additive overlay was computed by adding the two classification dates resulting in a change matrix image comprising 49 possible classes. This approach was implemented via a spatial model for several two date comparisons, shown in Table 4. To insure comparability between dates, only intersection areas were considered, using all of the dates of LULC products. LULC change detection products (Table 4) were produced for Mobile and Baldwin counties. Products highlighting the change since 1974 (the baseline, or first year of our study) were produced to better understand the magnitude of change through time. Decadal-scale change products were produced to understand the absolute magnitude of change on an approximate 10-year basis. We calculated decadal-scale change on the county and watershed scale: D'Olive Bay, Three Mile Creek, Fish River, Dog River, Fowl River, and Big Creek Lake.

Table 4. Dates for change detection products for Mobile and Baldwin Counties.

Mobile and Baldwin Counties		***Mobile and Baldwin Counties and Watershed Areas of Interest***	
Change Since 1974		**Decadal Change**	
Date 1	**Date 2**	**Date 1**	**Date 2**
1974	1979	1974	1984
1974	1984	1984	1996
1974	1988	1996	2008
1974	1991	1974	2008
1974	1996		
1974	2001		
1974	2005		
1974	2008		

5.3 Single Date LULC Map Accuracy Assessment

Product accuracy of Landsat-based, single date LULC maps was completed according to the following protocol. Locations on each date of classification were randomly sampled using a stratified random sampling approach in which the drawn sample per class was proportionally allocated according to class frequency. The randomly sampled locations were viewed on available digital reference data that included ground reference data, high resolution ortho-rectified aerial photography, high resolution multispectral

and panchromatic satellite data displays (from QuickBird and Corona sensors), digital elevation model data (for wetland class assessment), and NWI wetland cover type data (for wetland class assessment). C-CAP and NLCD products were used for qualitative comparison in assessing map accuracy. Landsat false color composites "RGBs" were used as a reference in LULC map accuracy assessment. We performed spatial averaging of available high resolution aerial and satellite data products into moderate resolution resolutions of Landsat data (30 meter and 60 meter, respectively) to understand the effects of spatial resolution on the appearance of LULC on multispectral imagery. Map accuracy assessment was also performed for C-CAP products to cross-compare Landsat LULC products from this study to those generated from C-CAP. C-CAP products are generated from multiple dates of Landsat data, whereas the products from our study are primarily generated from one Landsat data set per date. Accuracy statistics were summarized for several dates of LULC products: 1979, 1996, 2001, 2005, and 2008.

6. Results and Discussion

6.1 LULC Change Detection

6.1.1 Mobile and Baldwin Counties

Nine land-use and land-cover maps were produced showing the spatial distribution of seven landscape types in Mobile and Baldwin counties (Appendix I). Figure 3 shows the LULC products for 1974 (left) and 2008 (right), the temporal extremes of this project. The geospatial extent of each cover type for all data products are shown in Table 5. The most striking qualitative (visual) change between the LULC in 1974 and 2008 is the urban expansion around the City of Mobile and along the Eastern Shore. In the northeast portion of the study region, there has been a transition from upland forest to the upland herbaceous land-cover. However, Table 5 shows that the aforementioned land-cover transition has been temporally variable across the time series.

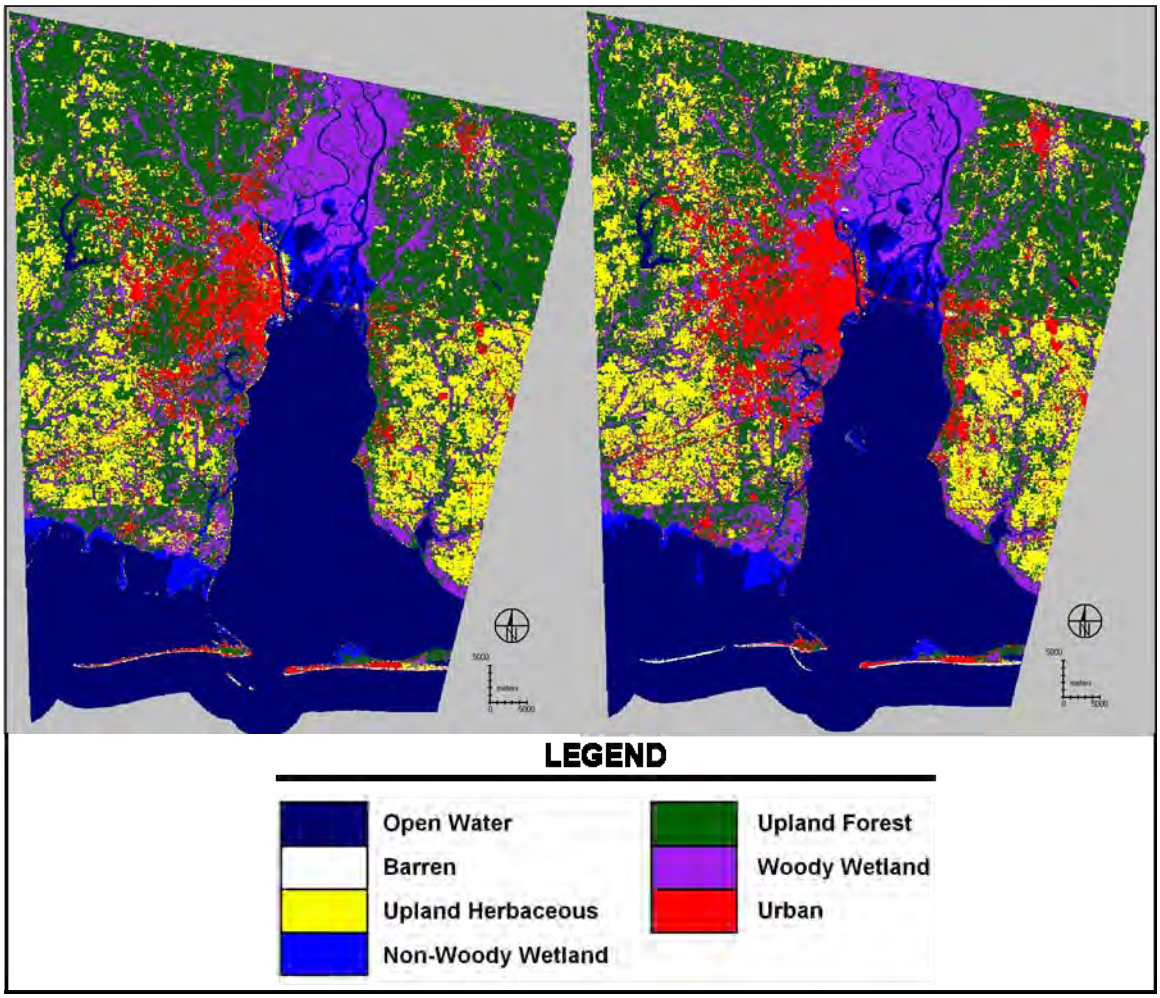


Figure 3. Landsat-derived land-use and land-cover data product for 1974 (left) and 2008 (right) showing surveyed area within Mobile and Baldwin counties.

Table 5. Landsat-derived geospatial statistics for Mobile and Baldwin counties.

Class	Coverage (acres)								
	1974	1979	1984	1988	1991	1996	2001	2005	2008
Open Water	450543	461839	462655	463506	464225	460829	469246	471609	465750
Barren	2521	4058	4492	2672	4965	4709	7046	7731	5305
Upland Herbaceous	180295	265938	158592	257969	254973	282511	258913	159564	197118
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Urban	80972	102416	102400	104125	104338	108455	113815	117144	128664

Percent coverage throughout the study period for Mobile and Baldwin counties for each landscape class is shown in Figure 4 and Table 6. Upland forest and open water are the most dominant LULC types, at around 30% throughout the study period; however, the open water class is more consistent through time. Upland forest and upland herbaceous are the most dynamic land-covers. These classes have an

inverse relationship, thus suggesting that the two transition between each other. Because the data were computed for the entire study area (and no pixel-by-pixel time series was constructed), we are not able to conclude with certainty that individual parcels of land are alternating between upland herbaceous and upland forest, though this is a common phenomenon with respect to pine plantation forestry. The dynamism within the upland herbaceous and upland forest land-covers is most dramatic between 1974 and 1984.

Both wetland classes, non-woody and woody, are fairly consistent through time. Between 1994 and 2008, there is a 0.17% reduction and a 0.45% increase of non-woody and woody wetlands, respectively. While the percentage loss and gain may seem trivial, it equates to a loss of 2395 acres of non-woody wetlands and a gain of 6488 acres of woody-wetlands. The scope of this project did not allow us to determine, at the land parcel level, if there is conversion between the two wetlands classes. However, we are able to conclude that between 1974 and 2008 there has been a net gain of 0.25%, or 4103 acres, for the two wetland classes.

Table 7 shows the relationship between upland herbaceous and upland forest. Negative values indicate that there was land loss during the period and positive values indicate land gain. The inverse relationship is consistent, except between 1988-1991 where the change for both classes was minimal (about 0.20%). The exchange of land is almost (within 1%) one-to-one over the entire study region for four of the change intervals.

A small portion (always <1.0%) of the study region is barren land. This LULC classification includes bare sand (beaches), which are mostly found on Dauphin Island, Pelican Island, and Gulf Shores. This land-cover is affected by beach re-nourishment efforts and the removal of beaches post-Katrina, for example. The urban landscape is consistently expanding, growing from 5.59% in 1974 to 8.88% in 2008. Additional geospatial products depicting urban land cover change is found in Appendix I and II.

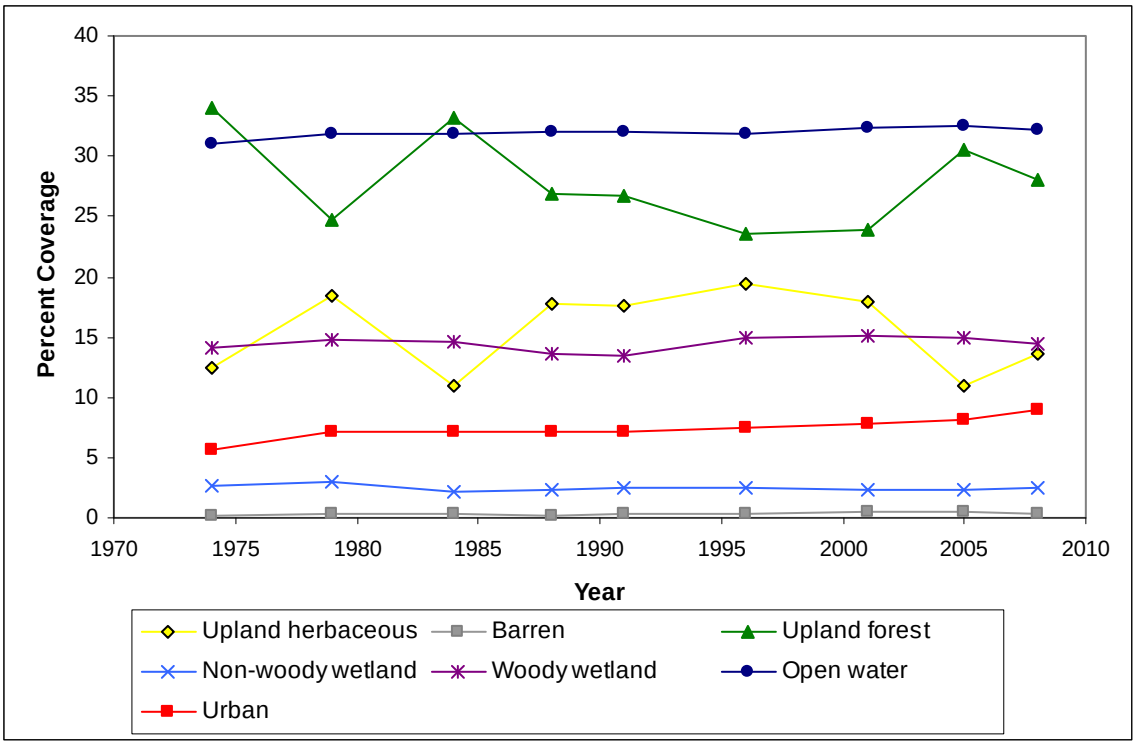

Figure 4. Percent coverage for each land-use and land-cover class for Mobile and Baldwin counties; tabular data is presented in Table 6.

Table 6. Percent coverage for each land-use and land-cover class for Mobile and Baldwin counties.

Class	Percent Coverage								
	1974	1979	1984	1988	1991	1996	2001	2005	2008
Open Water	31.10	31.88	31.93	31.99	32.04	31.81	32.39	32.55	32.15
Barren	0.17	0.28	0.31	0.18	0.34	0.33	0.49	0.53	0.37
Upland Herbaceous	12.44	18.36	10.94	17.80	17.60	19.50	17.87	11.01	13.61
Non-woody Wetland	2.59	2.91	2.08	2.33	2.51	2.49	2.38	2.28	2.42
Upland Forest	34.05	24.80	33.15	26.96	26.80	23.50	23.97	30.54	28.07
Woody Wetland	14.06	14.70	14.52	13.55	13.51	14.89	15.06	15.00	14.51
Urban	5.59	7.07	7.07	7.19	7.20	7.49	7.86	8.09	8.88

Table 7. Percent coverage change for selected LULC types.

Class	Percent Coverage Change							
	1974-1979	1979-1984	1984-1988	1988-1991	1991-1996	1996-2001	2001-2005	2005-2008
Upland Herbaceous	5.91	-7.41	6.86	-0.20	1.90	-1.63	-6.86	2.59
Upland Forest	-9.25	8.35	-6.18	-0.17	-3.30	0.46	6.57	-2.47

Land-use and land-cover change over time since 1974 (see Table 4) is shown in Figure 5 and Table 8. On Figure 5, the *x*-axis data points represent the latter extreme of temporal change – so 1979 represents change from 1974 to 1979 and 1984 represents change from 1979 to 1984. Positive values indicate an increase in percent land-use or land-cover since 1974 and negative values indicate a reduction in percent land-use or land-cover loss. One would speculate that largest percent changes should occur when considering the longest period of time (i.e., the 2008 data point which represents change between 1974 and 2008); however the largest variances occurred from 1974-1996, followed by 1974-1979.

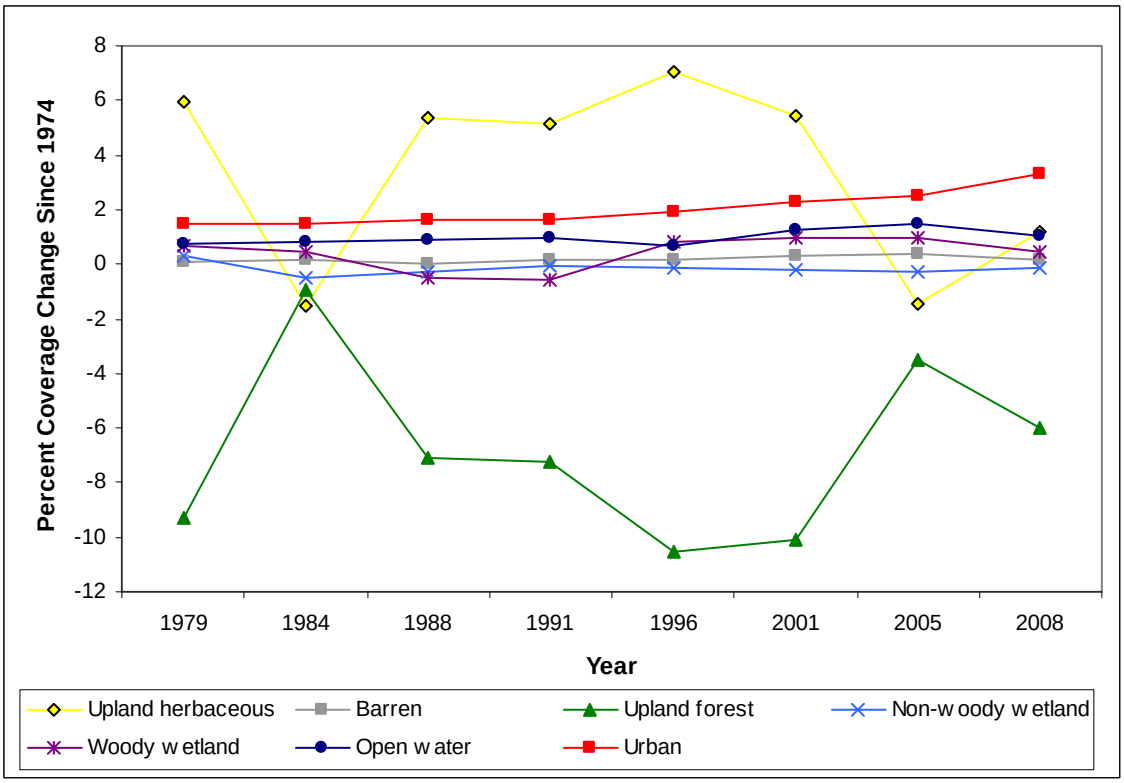

Figure 5. Percent coverage change since 1974 for Mobile and Baldwin counties; tabular data are presented in Table 7. The data shown for 1979 represents change from 1974-1979 and point at 1984 is change from 1974-1984, for example.

Table 8. Percent coverage change since 1974 for Mobile and Baldwin counties.

Class	Percent Coverage Change Since 1974							
	1974-1979	1974-1984	1974-1988	1974-1991	1974-1996	1974-2001	1974-2005	1974-2008
Open Water	0.78	0.83	0.89	0.94	0.71	1.29	1.45	1.05
Barren	0.11	0.14	0.01	0.17	0.15	0.31	0.36	0.19
Upland Herbaceous	5.91	-1.50	5.36	5.15	7.06	5.43	-1.43	1.16
Non-Woody Wetland	0.33	-0.51	-0.26	-0.08	-0.10	-0.21	-0.31	-0.17
Upland Forest	-9.25	-0.90	-7.09	-7.25	-10.55	-10.08	-3.51	-5.98
Woody Wetland	0.64	0.46	-0.51	-0.55	0.83	1.00	0.94	0.45
Urban	1.48	1.48	1.60	1.61	1.90	2.27	2.50	3.29

Land-use and land-cover geospatial statistics for Mobile and Baldwin counties on a decadal time scale (1974-1988; 1984-1996; 1996-2008) and over the 34-year study period (1974-2008) is shown in Table 9. Figure 6 shows these data graphically for the decadal time steps, and does not include those data for the entire study period. The data shown in Table 9 and Figure 6 reinforce that absolute change over time is quite minimal (around 1%), except for the upland herbaceous and upland forest classes. However, when landscapes only comprise a small percentage of the total (urban, non-woody wetland, and barren each average <10%) small percentage change actually represents a large relative change. As stated above in the discussion of wetlands, minimal change over Mobile and Baldwin counties equates to about 145,000 acres, which maybe more significant when planning restoration/conservation efforts.

Table 9. Land-use and land-cover geospatial statistics for Mobile and Baldwin counties. Change on a decadal scale (1974-1988; 1984-1996; 1996-2008) and for the 34-year study period is provided.

Class	Change (acres)				Percent Change			
	1974-1984	1984-1996	1996-2008	1974-2008	1974-1984	1984-1996	1996-2008	1974-2008
Open Water	12113	-1826	4921	15208	0.83	-0.12	0.34	1.05
Barren	1971	218	596	2784	0.14	0.02	0.04	0.19
Upland Herbaceous	-21703	123919	-85392	16823	-1.50	8.55	-5.89	1.16
Non-woody Wetland	-7336	5941	-1000	-2394	-0.51	0.41	-0.07	-0.17
Upland Forest	-13013	-139791	66205	-86599	-0.90	-9.64	4.57	-5.98
Woody Wetland	6737	5290	-5538	6489	0.46	0.37	-0.38	0.45
Urban	21428	6055	20209	47692	1.48	0.42	1.39	3.29

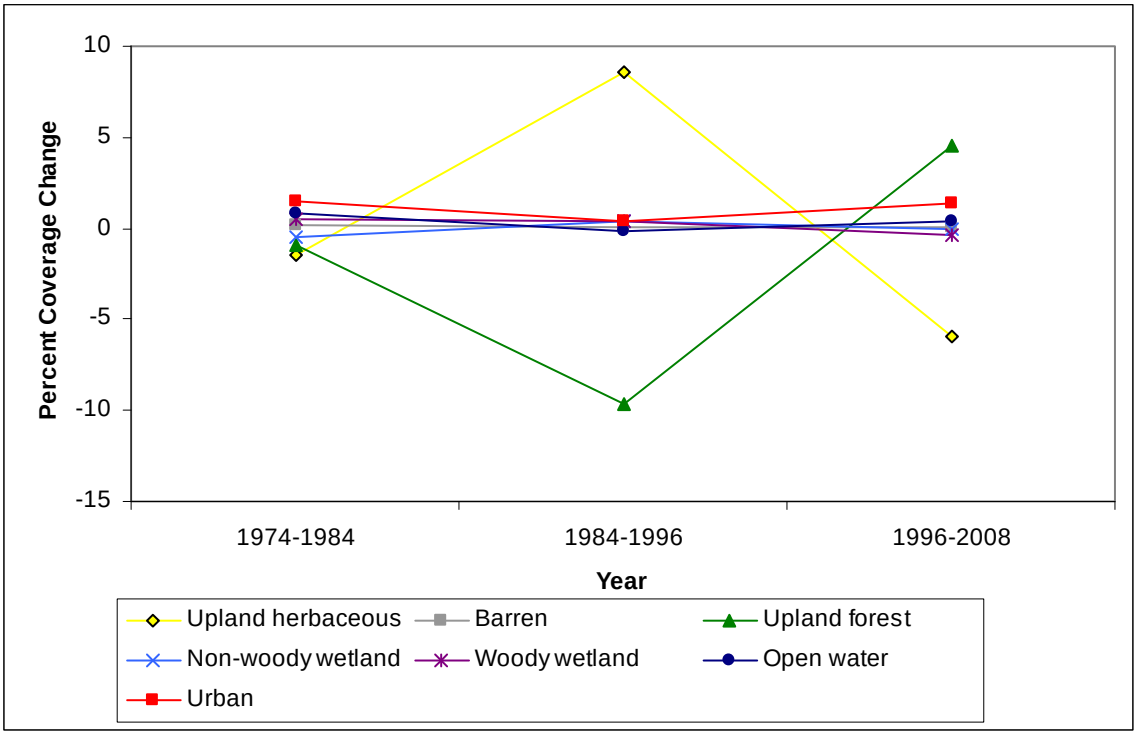

Figure 6. Decadal land-use and land-cover change for Mobile and Baldwin counties.

An alternative method to represent LULC data is to normalize change in each class to the baseline (1974). Figure 7 shows this analysis for all landscapes except barren. The relatively small absolute change for wetlands, discussed above, that considered each LULC classification percent relative to all classifications, are now larger. For example, the urban landscape is consistently increases through time. There is an approximate 30% increase in urban land-cover between 1974 and 1979, with that change increasing to almost 60% when considering the entire time series. We are also able to better appreciate the fluctuations occurring for the non-woody wetlands.

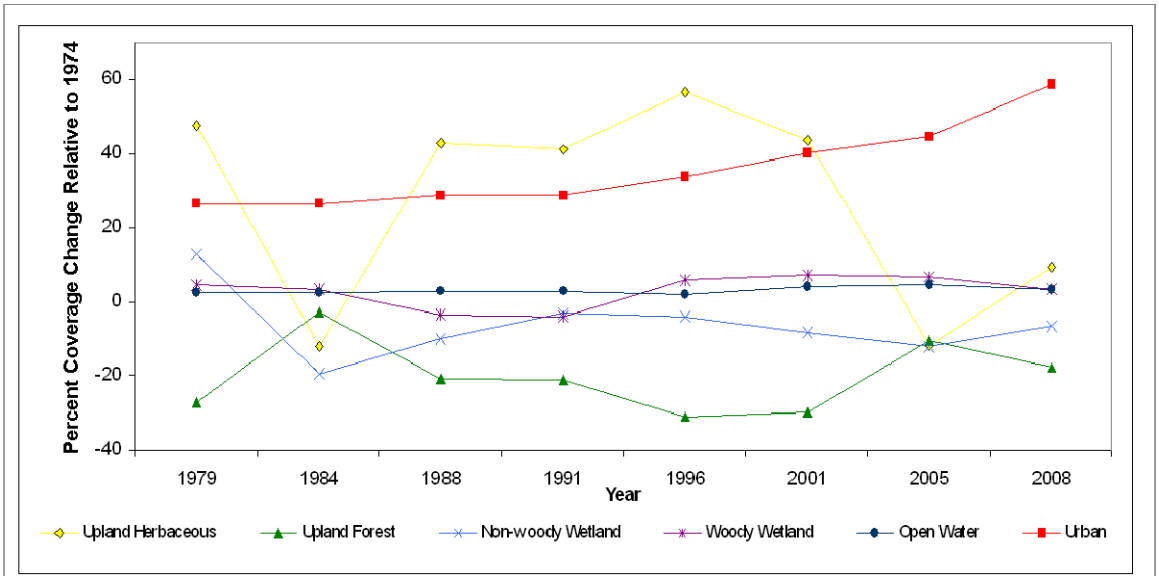

Figure 7. Percent coverage change relative to 1974 for each land-use and land-cover class (except barren) for Mobile and Baldwin counties. Barren was excluded from the figure because this land-use comprises a small percent of the total coverage (<0.5%) and therefore small acreage changes are reflected with a distortional percent change.

6.1.2 Watersheds of Interest

Appendix II shows the spatial distribution of LULC (and the associated geospatial statistics) on a decadal-scale for the six watersheds of interest. Tables 10-13 and Figures 8-11 quantitatively depict decadal-scale changes for D'Olive Bay, Three Mile Creek, Upper Fish River, Big Creek Lake, and Dog River, and Fowl River. D'Olive Bay, Fish River, Big Creek Lake, Dog River and Fowl River are predominately upland forested landscapes, while the Three Mile Creek is largely urbanized. Three Mile Creek showed that approximately 90% of the total urban expansion and loss of upland forest between 1974 and 1984. D'Olive Bay also experienced comparable urban expansion between 1974 and 1984. However, between 1984 and 1996 there was a dramatic loss of urbanized areas and increase of upland forested land. The details of this transition, including the drivers for change, warrant more investigation.

Table 10. Land-use and land-cover geospatial statistics for D'Olive Bay. Change on a decadal scale (1974-1988; 1984-1996; 1996-2008) and for the 34-year study period is provided.

Class	Change (acres)				Percent Change			
	1974-1984	1984-1996	1996-2008	1974-2008	1974-1984	1984-1996	1996-2008	1974-2008
Open Water	2	22	28	52	0.0	0.0	0.3	0.4
Barren	5	17	113	135	0.1	0.1	1.4	1.6
Upland Herbaceous	-248	432	-215	-31	-4.7	-3.5	-2.6	-10.8
Non-Woody Wetland	6	54	-43	17	0.1	0.5	-0.5	0.1
Upland Forest	-338	2143	-487	1318	-6.5	17.3	-5.9	4.9
Woody Wetland	64	108	-229	-57	1.2	-4.5	-2.8	-6.0
Urban	508	225	833	1566	17.8	-10.0	10.1	9.8

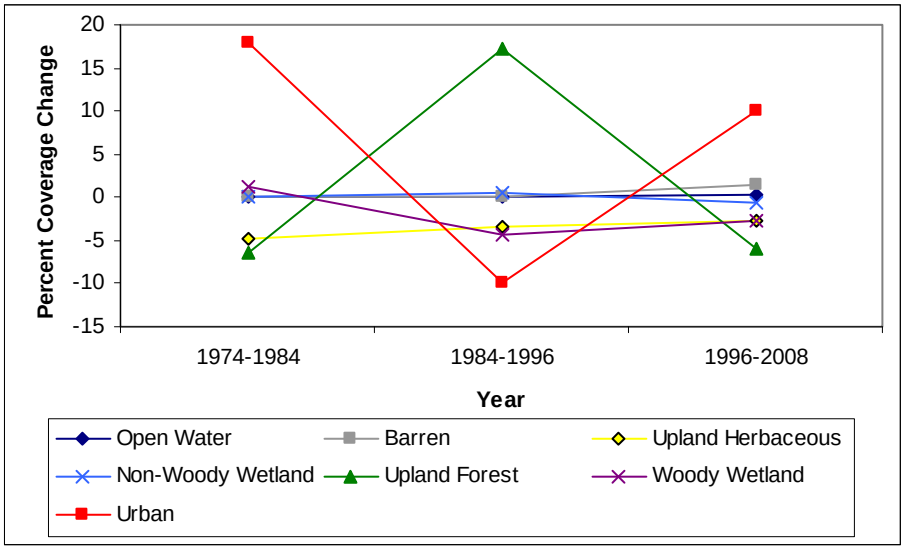

Figure 8. Decadal land-use and land-cover change for D'Olive Bay.

Table 11. Land-use and land-cover geospatial statistics for Three Mile Creek. Change on a decadal scale (1974-1988; 1984-1996; 1996-2008) and for the 34-year study period is provided.

Class	Change (acres)				Percent Change			
	1974-1984	1984-1996	1996-2008	1974-2008	1974-1984	1984-1996	1996-2008	1974-2008
Open Water	37	69	104	210	0.2	0.3	0.6	1.1
Barren	96	25	-111	10	0.4	0.2	-0.6	0.0
Upland Herbaceous	-830	741	-889	-978	-4.3	3.8	-4.5	-5.0
Non-Woody Wetland	-6	97	-69	22	-0.1	0.5	-0.3	0.1
Upland Forest	-2995	-566	48	-3513	-15.4	-3.0	0.3	-18.1
Woody Wetland	257	87	-111	233	1.3	0.4	-0.5	1.2
Urban	3447	-452	1028	4023	17.8	-2.3	5.2	20.7

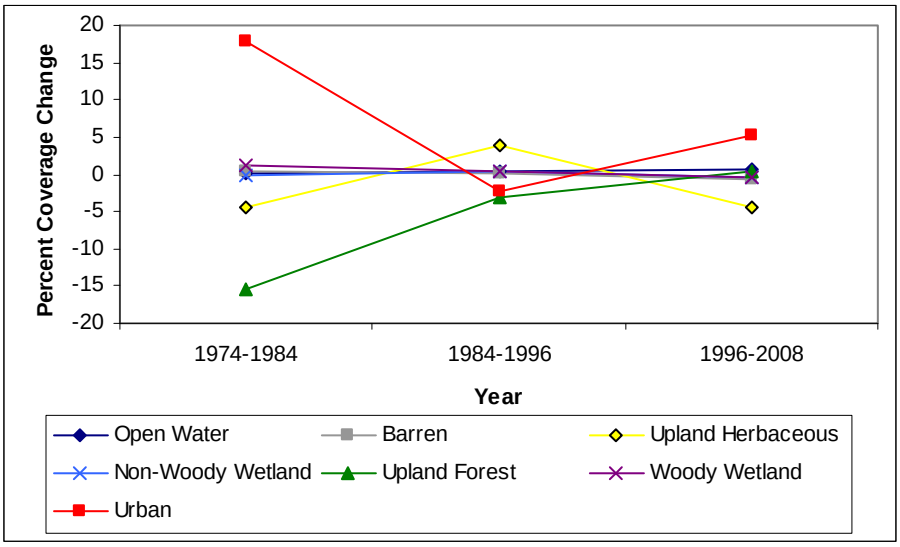

Figure 9. Decadal land-use and land-cover change for Three Mile Creek.

Table 12. Land-use and land-cover geospatial statistics for Upper Fish River. Change on a decadal scale (1974-1988; 1984-1996; 1996-2008) and for the 34-year study period is provided.

Class	Change (acres)				Percent Change			
	1974-1984	1984-1996	1996-2008	1974-2008	1974-1984	1984-1996	1996-2008	1974-2008
Open Water	435	-68	56	423	0.5	-0.1	0.1	0.4
Barren	-9	439	35	465	0.0	0.4	0.0	0.4
Upland Herbaceous	-4069	14161	-12242	-2150	-2.6	12.4	-11.8	-2.1
Non-Woody Wetland	-256	491	-197	38	-0.2	0.5	-0.2	0.0
Upland Forest	78	-14229	10795	-3356	1.2	-14.9	10.4	-3.2
Woody Wetland	435	740	-274	901	0.9	0.3	-0.3	0.9
Urban	117	1738	1823	3678	0.3	1.5	1.8	3.5

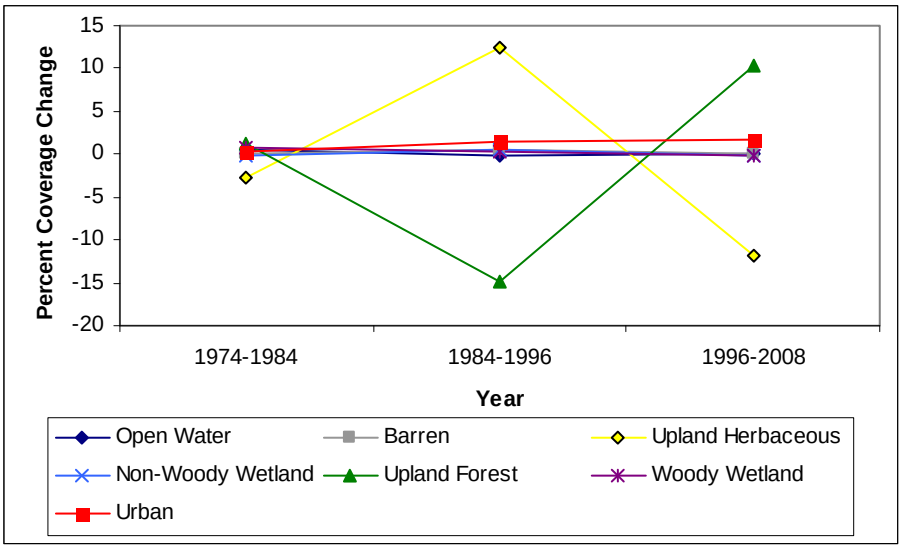

Figure 10. Decadal land-use and land-cover change for Upper Fish River.

Table 13. Land-use and land-cover geospatial statistics for Dog River. Change on a decadal scale (1974-1988; 1984-1996; 1996-2008) and for the 34-year study period is provided.

Class	Change (acres)				Percent Change			
	1974-1984	1984-1996	1996-2008	1974-2008	1974-1984	1984-1996	1996-2008	1974-2008
Open Water	205	-26	44	223	1.2	-0.2	0.3	1.3
Barren	-6	63	34	91	-0.1	0.4	0.2	0.5
Upland Herbaceous	-115	1696	-1473	108	-0.6	9.9	-8.6	0.7
Non-Woody Wetland	-39	130	-43	48	-0.2	0.8	-0.3	0.3
Upland Forest	-1665	-1767	644	-2788	-9.8	-10.3	3.7	-16.4
Woody Wetland	223	-268	-70	-115	1.4	-1.6	-0.4	-0.6
Urban	1395	175	863	2433	8.2	1.0	5.1	14.3

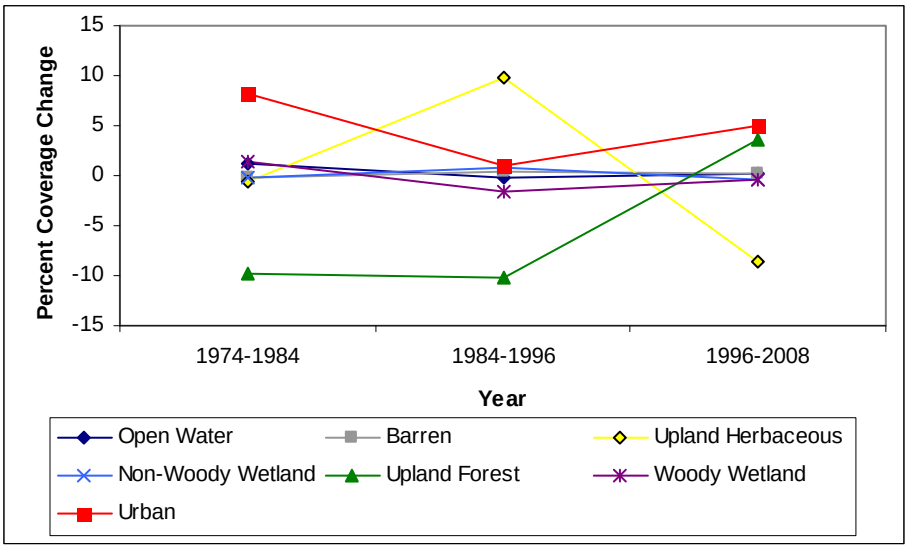

Figure 11. Decadal land-use and land-cover change for Dog River.

Table 14. Land-use and land-cover geospatial statistics for Fowl River. Change on a decadal scale (1974-1988; 1984-1996; 1996-2008) and for the 34-year study period is provided.

Class	Change (acres)				Percent Change			
	1974-1984	1984-1996	1996-2008	1974-2008	1974-1984	1984-1996	1996-2008	1974-2008
Open Water	199	82	48	329	0.5	0.2	0.2	0.9
Barren	40	107	-51	96	0.1	0.3	-0.2	0.2
Upland Herbaceous	-2246	7246	-5173	-172	-5.6	18.1	-12.9	-0.4
Non-Woody Wetland	-29	140	-79	32	0.0	-0.6	0.7	0.1
Upland Forest	574	-7122	3860	-2688	1.5	-17.8	9.7	-6.6
Woody Wetland	774	-872	677	579	1.9	-2.1	1.7	1.5
Urban	689	419	714	1822	1.8	1.0	1.8	4.6

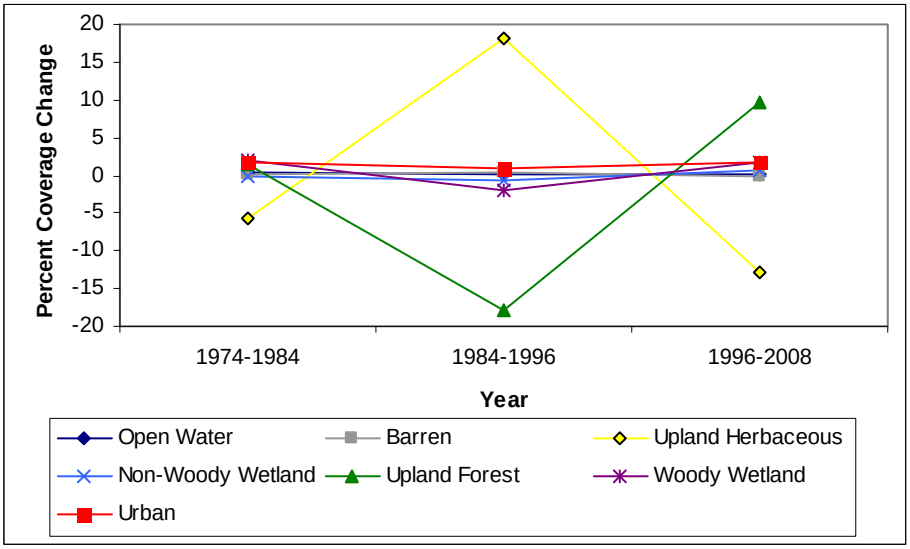

Figure 12. Decadal land-use and land-cover change for Fowl River.

Table 15. Land-use and land-cover geospatial statistics for Big Creek Lake. Change on a decadal scale (1974-1988; 1984-1996; 1996-2008) and for the 34-year study period is provided.

Class	Change (acres)				Percent Change			
	1974-1984	1984-1996	1996-2008	1974-2008	1974-1984	1984-1996	1996-2008	1974-2008
Open Water	608	-82	-1	525	0.9	-0.2	0.0	0.7
Barren	9	83	43	135	0.0	0.2	0.0	0.2
Upland Herbaceous	-3560	12507	-4002	4946	-5.3	18.6	-5.9	7.4
Non-Woody Wetland	56	178	-27	208	0.1	0.2	0.0	0.3
Upland Forest	1890	-13062	3315	-7857	2.8	-19.5	5.0	-11.7
Woody Wetland	418	209	-613	14	0.6	0.3	-0.9	0.0
Urban	581	166	1286	2033	0.9	0.2	2.0	3.1

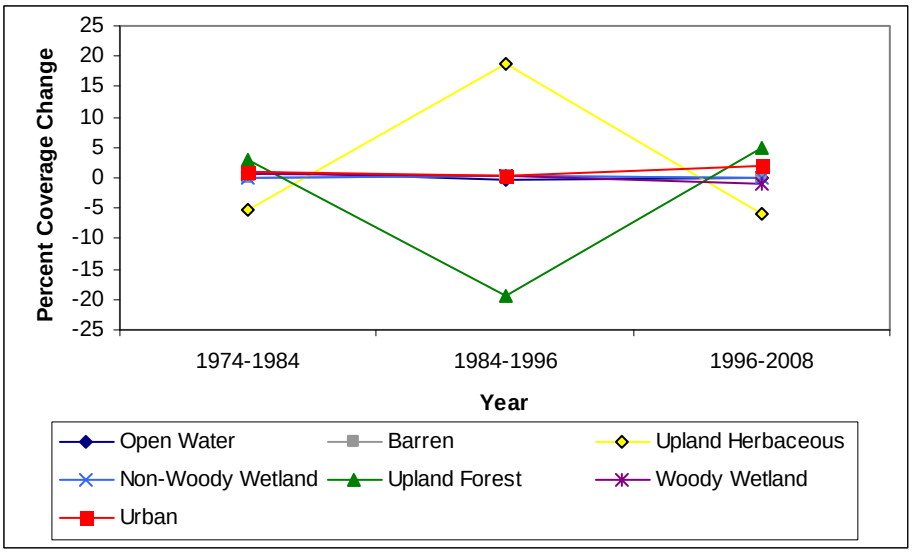

Figure 13. Decadal land-use and land-cover change for Big Creek Lake.

6.1.3 Urban Growth for Mobile and Baldwin Counties

Urban expansion in Mobile and Baldwin counties during the study period (1974-2008), and for the northern Mobile Bay demonstration region on a decadal time scale, is shown in Figures 14 and 15. Appendix II includes figures showing decadal-scale urban expansion for the watershed areas of interest. These satellite-based estimates indicate that during the 34-year study period urban areas increased from 80,972 to 128,662 acres, representing a 58.9% increase, or 1.73% per annum. The period from 1974 to 1984 shows the greatest expansion in the urban landscape (21428 acres, or 1.48%, c.f. Table 7). The urban expansion occurring from 1996 and 2008 was comparable to the expansion observed from 1974 to 1984 in absolute acres classified as urban; however the spatial distributions of the expansions appear to be quite different.

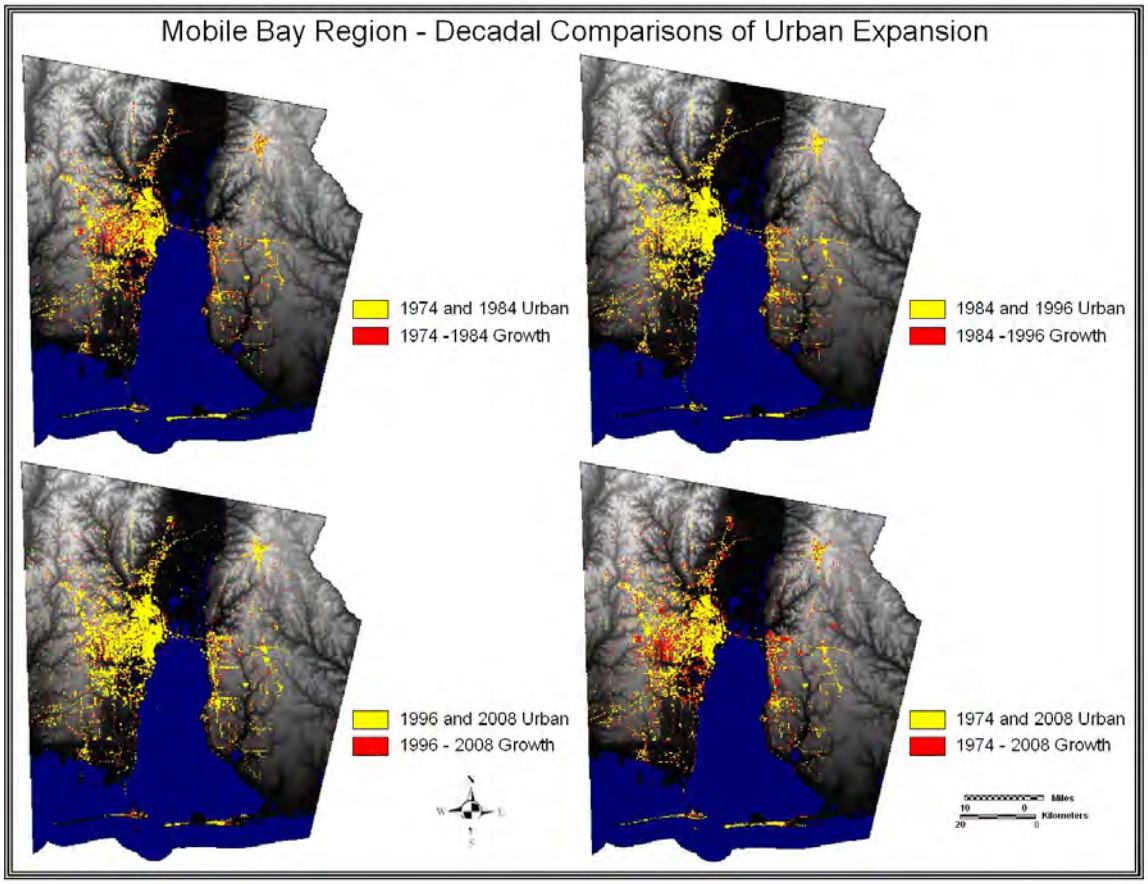

Figure 14. Decadal-scale of urban expansion for Mobile and Baldwin counties. The area shown is common to all four dates used in the analysis, done in an effort to standardize change comparisons across all dates.

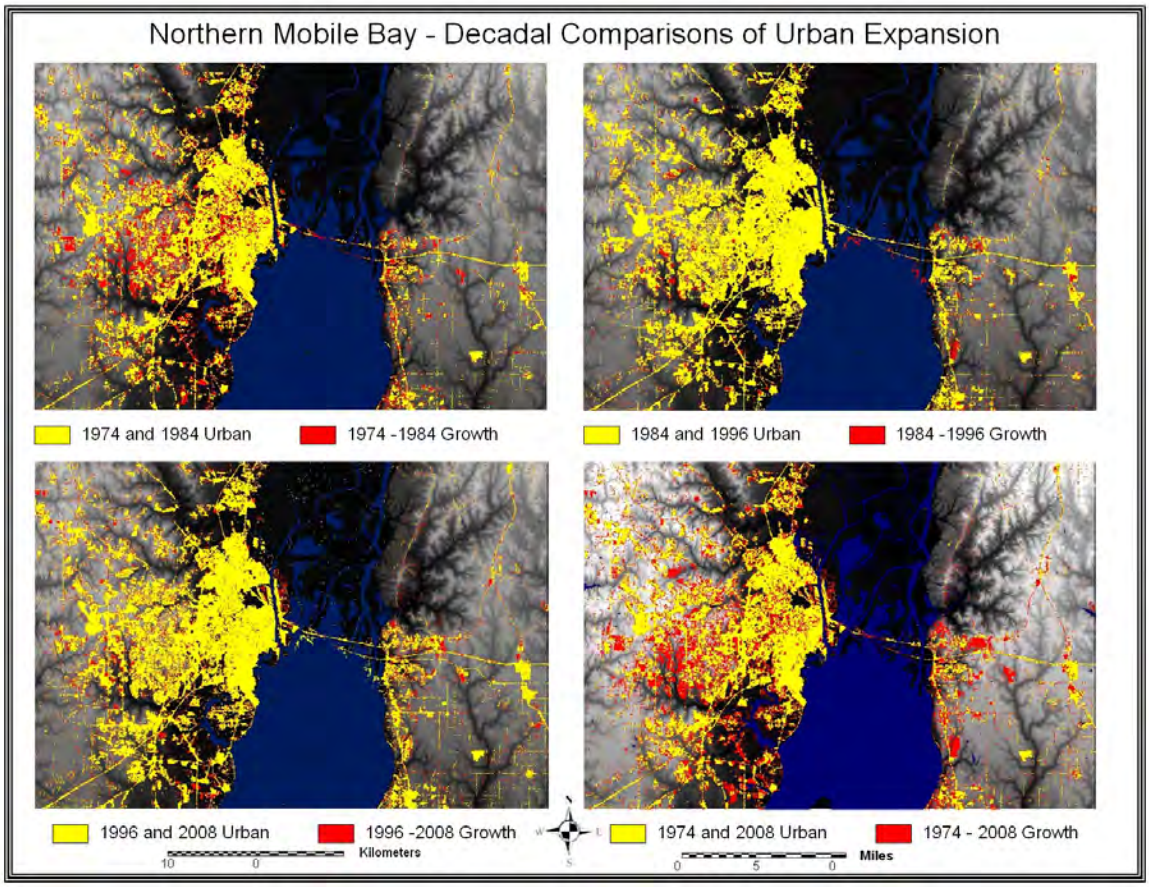

Figure 15. Enlarged comparison of urban expansion for Northern Mobile Bay, including the city of Mobile, on a decadal time scale and for the duration of the study.

Table 16 shows the conversion of the land-use and land-cover classes to the urban landscape for Mobile and Baldwin counties between 1974 and 2008. In Table 16, the landscape listed to the left of the arrow indicates the landscape in 1974 that was converted to urban by 2008. This analysis is useful because we are able to determine which land types were most affected by the spreading urbanization. The data shown in Table 16 indicate that approximately 34% of the acres that were upland forest in 1974 were converted to urban by 2008. Upland herbaceous was the next most affected land-cover – approximately 7% of the baseline land-cover was converted to urban.

Table 16. Geospatial trends in urban expansion for Mobile and Baldwin counties from 1974-2008, based on Landsat data analysis. Converted acres indicate the total acres converted from the 1974 class to urban in 2008.

1974 Class → 2008 Class	1974 Class (Acres)	Converted (Acres)	Percent Converted (Acres)
Open water → Urban	450543	412	0.32
Barren → Urban	2521	241	0.19
Upland herbaceous →Urban	180295	9570	7.44
Non-woody wetland → Urban	37475	769	0.60
Upland forest → Urban	493301	44182	34.34
Woody wetland → Urban	203704	2663	2.07

6.2 Single Date LULC Map Accuracy Assessment

Table 17 summarizes accuracy assessment for the 1979, 1996, 2001, 2005, and 2008 LULC classifications. The overall accuracy ranged from 83.13 (2005) to 89.33 (1979) and the Kappa values for these classifications ranged from 0.78 (2005) to 0.87 (1979). The sampling intensity for these assessments ranged from 150 (1979) to 190 (2008) total random samples per classification. In all cases, the overall accuracy exceeded 80% and the Kappa either approached or exceeded 0.8 (on a scale of 0 to 1). The use of Landsat MSS data (1979, at 60 m, rather than post 1984 at 30 m) did not seem to lower the accuracy. However, we acknowledge only one MSS product was assessed for accuracy and additional accuracy assessment is needed to assess further.

Table 17. Overall accuracy of 1979, 1996, 2001, 2005, and 2005 land-use land-cover classifications compared to available reference data.

Year	Overall Accuracy (%)	Overall Kappa	Total Samples
1979	89.33	0.87	150
1996	86.88	0.84	160
2001	88.00	0.85	150
2005	83.13	0.78	160
2008	89.06	0.86	192

Accuracy assessment was completed for the 2005 C-CAP product produced prior to Hurricane Katrina. The 2005 C-CAP classification yielded an overall accuracy of 86.25% compared to the 2005 Landsat result of 83.13% overall accuracy. The C-CAP product produced a higher overall Kappa value of 0.83 compared to the Landsat result of 0.78. The C-CAP and the Landsat classification were both assessed using 160 randomly sampled points. The higher relative accuracy of the C-CAP product was expected, in part due to C-CAP employing multiple Landsat dates to produce the classification, and in part due to the C-CAP process being more labor and resource intensive. The 2005 Landsat product was one of the first ones produced in this study, which may also partially help explain its lower accuracy. However, even as is, the overall accuracy of all of the non-C-CAP products appears to be acceptable.

6.3 End-User Interface

This project was conceived and implemented in collaboration with MBNEP. The NASA team met with the MBNEP team on six occasions (November, January, February, April, June, and September) to discuss and refine project deliverables and to communicate interim project results. MBNEP finalized the seven land-use and land-cover classifications and determined several 'areas of interest' for more focused LULC mapping and analysis: D'Olive Bay, Three Mile Creek, Fish River, Dog River, Fowl River, Upper Big Creek Lake, and northern Mobile Bay. In addition to the continual communication with MBNEP, briefings on this project have been delivered in several forums throughout the Gulf of Mexico (NASA SSC Technical Briefing, January; GOMA Federal Working Group meeting, March; NOAA Gulf of Mexico Regional Team Meeting, May; NASA SSC Strategic Plan Workshop, May and August).

7. Future Deliverables and Additional Products

All project-relevant geospatial data and final data products will be transferred to Mobile Bay NEP and NOAA-NCDDC. Mobile Bay NEP has requested static images of the data products (*.jpg) and files compatible with ArcGIS. The NASA SSC team is employing MERMAid to integrate project data in Regional Ecosystem Data Management (REDM) to provide access to data and information for federal, state, local, and non-governmental agencies or organizations and academics. All NASA-generated products will be available for NOAA Integrated Ecosystem Assessments (IEAs). Additional products, at the request of MBNEP, will be produced, pending additional funding.

8. References

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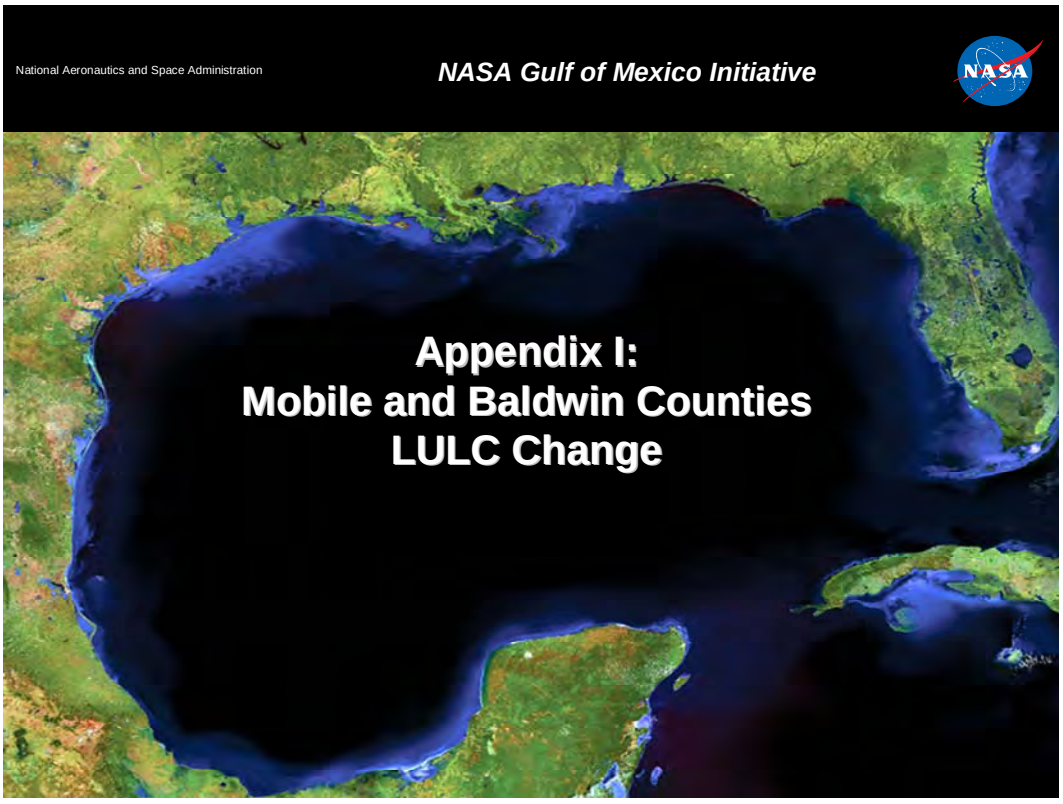
Appendix I

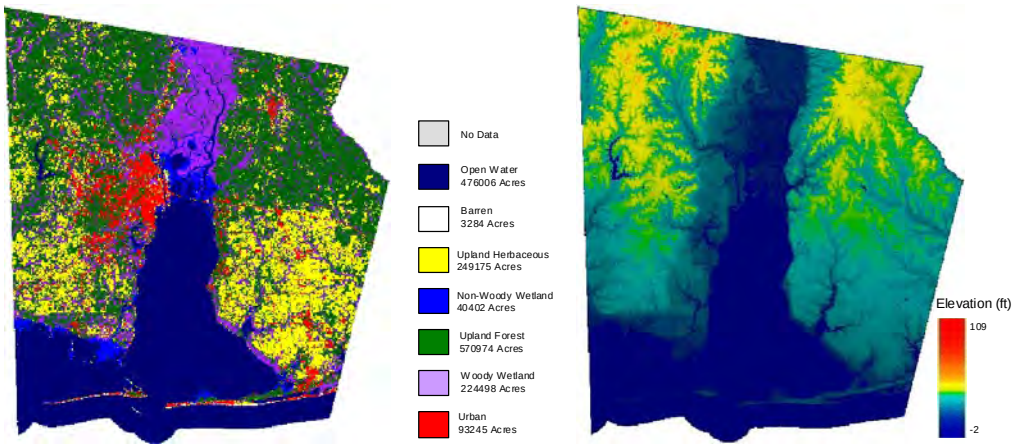
LULC products and geospatial statistics showing Mobile and Baldwin counties for each date (identified in Figure 12).

Appendix II

LULC products and geospatial statistics for selected watersheds of interest.

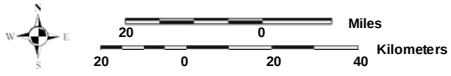


Mobile Bay – 1974 Land-Use & Land-Cover Classification

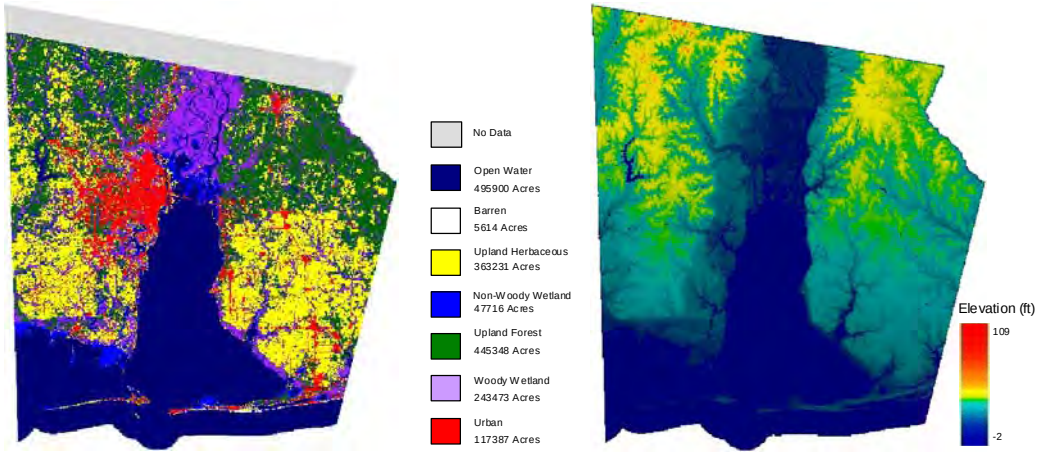


Landsat Multispectral Scanner Data
Acquired: 11/12/1974

USGS 30 Meter Elevation Model
Mobile & Baldwin Counties



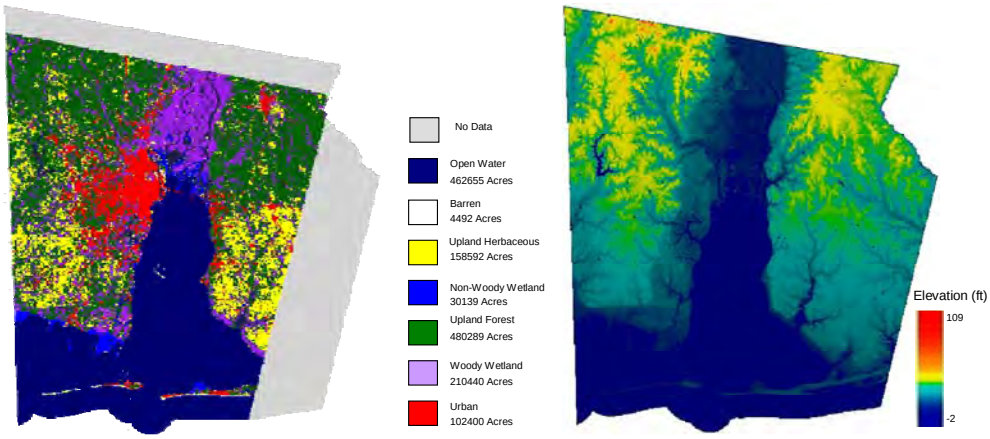
Mobile Bay – 1979 Land-Use & Land-Cover Classification



Landsat Multispectral Scanner Data
Acquired: 10/26/1979

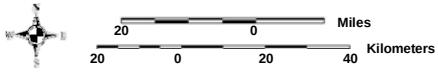
USGS 30 Meter Elevation Model
Mobile & Baldwin Counties

Mobile Bay – 1984 Land-Use & Land-Cover Classification

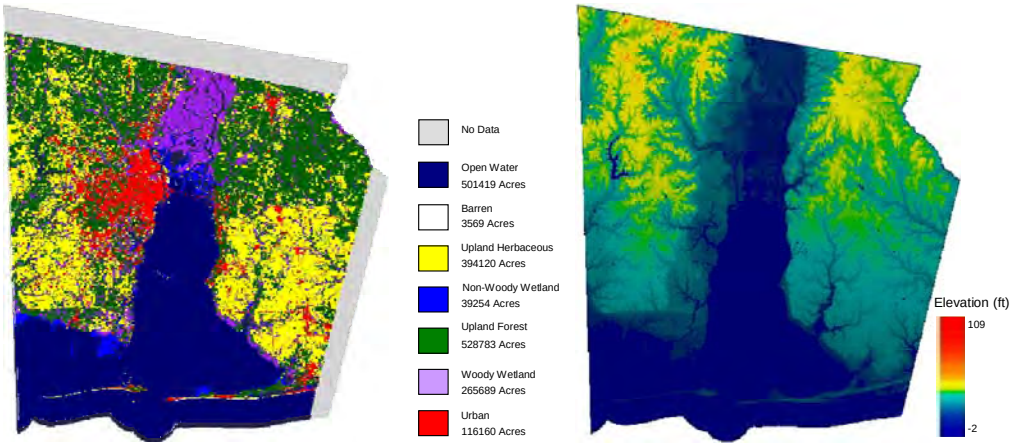


Landsat Multispectral Scanner Data
Acquired : 09/06/1984

USGS 30 Meter Elevation Model
Mobile & Baldwin Counties

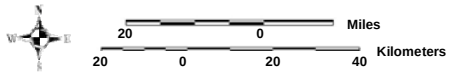


Mobile Bay – 1988 Land-Use & Land-Cover Classification

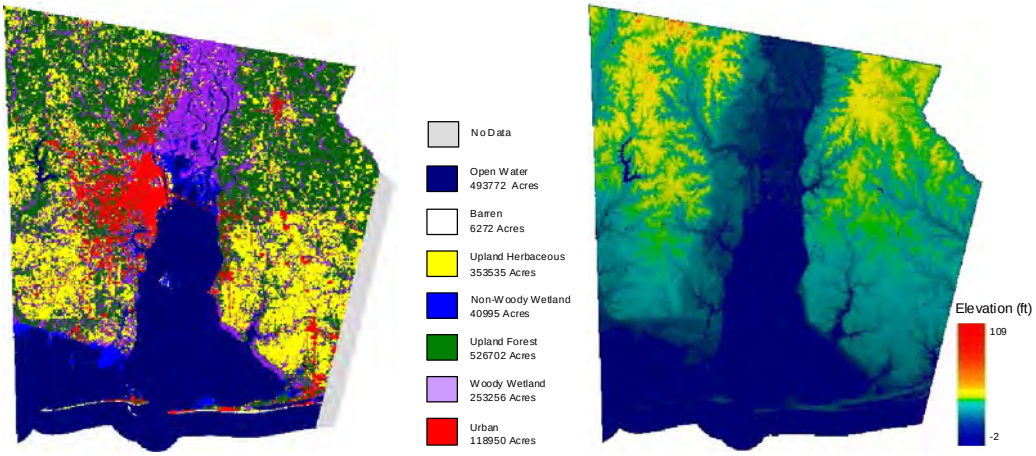


Landsat Thematic Mapper Data
Acquired: 02/22/1988

USGS 30 Meter Elevation Model
Mobile & Baldwin Counties



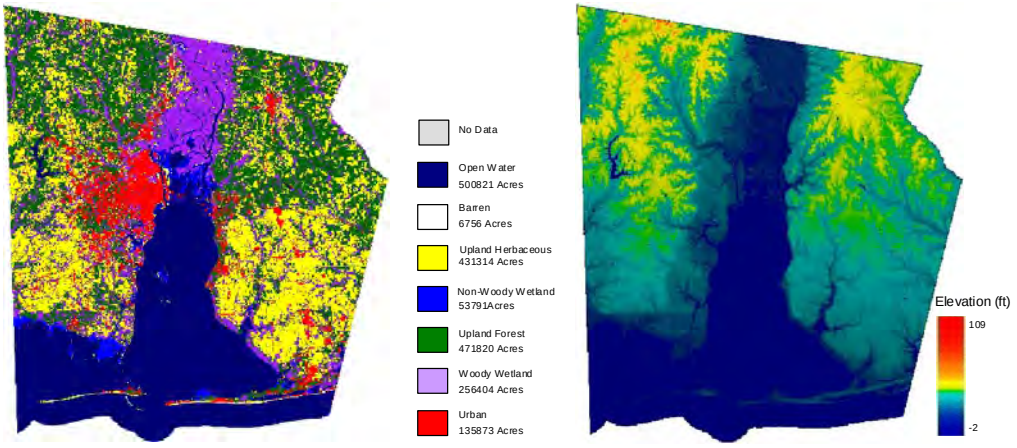
Mobile Bay – 1991 Land-Use & Land-Cover Classification



Landsat Thematic Mapper Data
Acquired: 09/26/1991

USGS 30 Meter Elevation Model
Mobile & Baldwin Counties

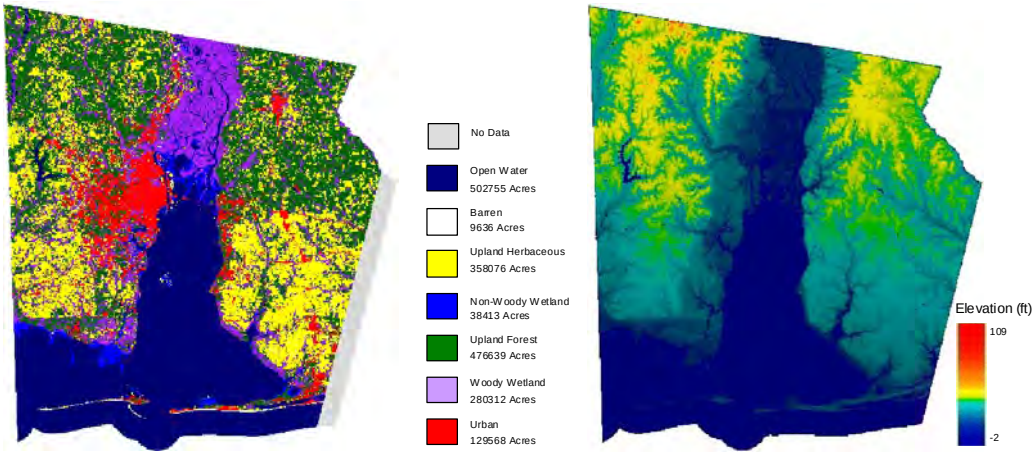
Mobile Bay – 1996 Land-Use & Land-Cover Classification



Landsat Thematic Mapper Data
Acquired : 01/27/1996

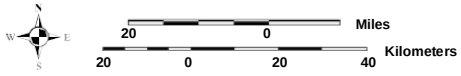
USGS 30 Meter Elevation Model
Mobile & Baldwin Counties

Mobile Bay – 2001 Land-Use & Land-Cover Classification

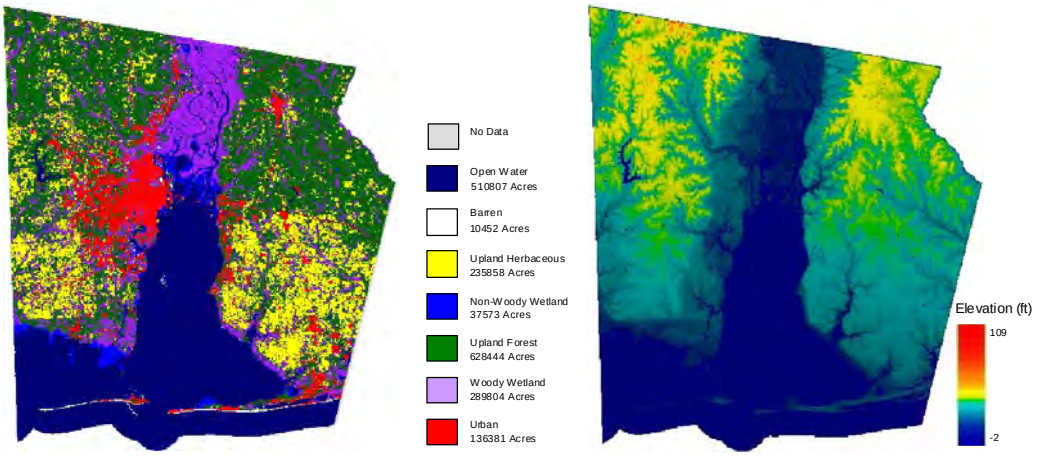


Landsat Thematic Mapper Data
Acquired : 03/05/2001

USGS 30 Meter Elevation Model
Mobile & Baldwin Counties

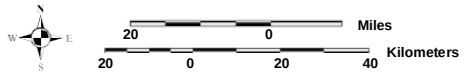


Mobile Bay – 2005 Land-Use & Land-Cover Classification

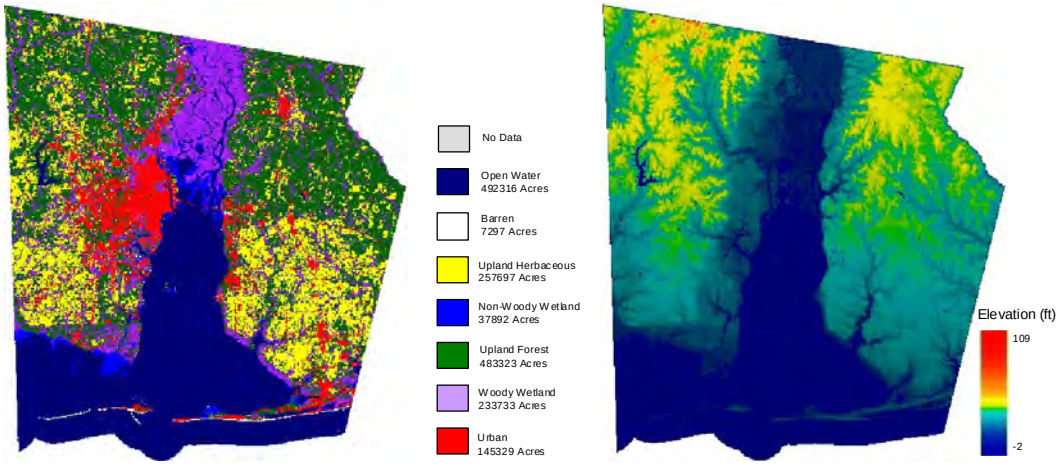


Landsat Thematic Mapper Data
Acquired : 03/24/2005

USGS 30 Meter Elevation Model
Mobile & Baldwin Counties

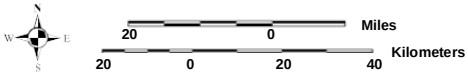


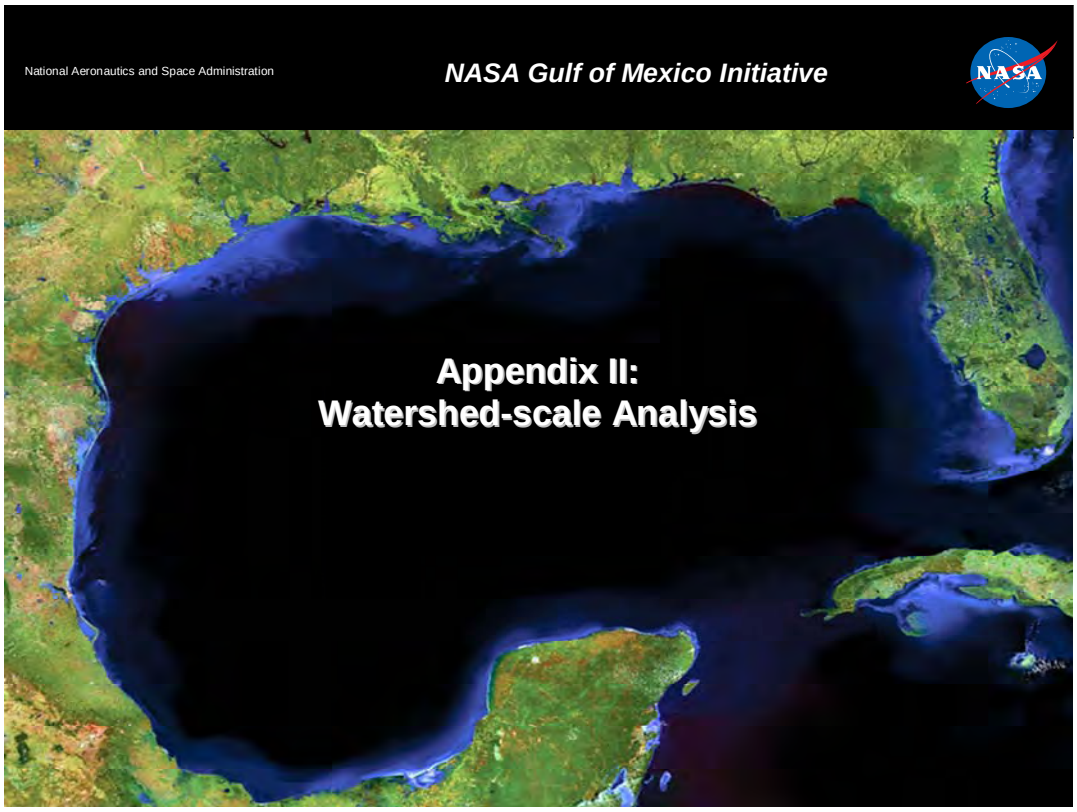
Mobile Bay – 2008 Land-Use & Land-Cover Classification



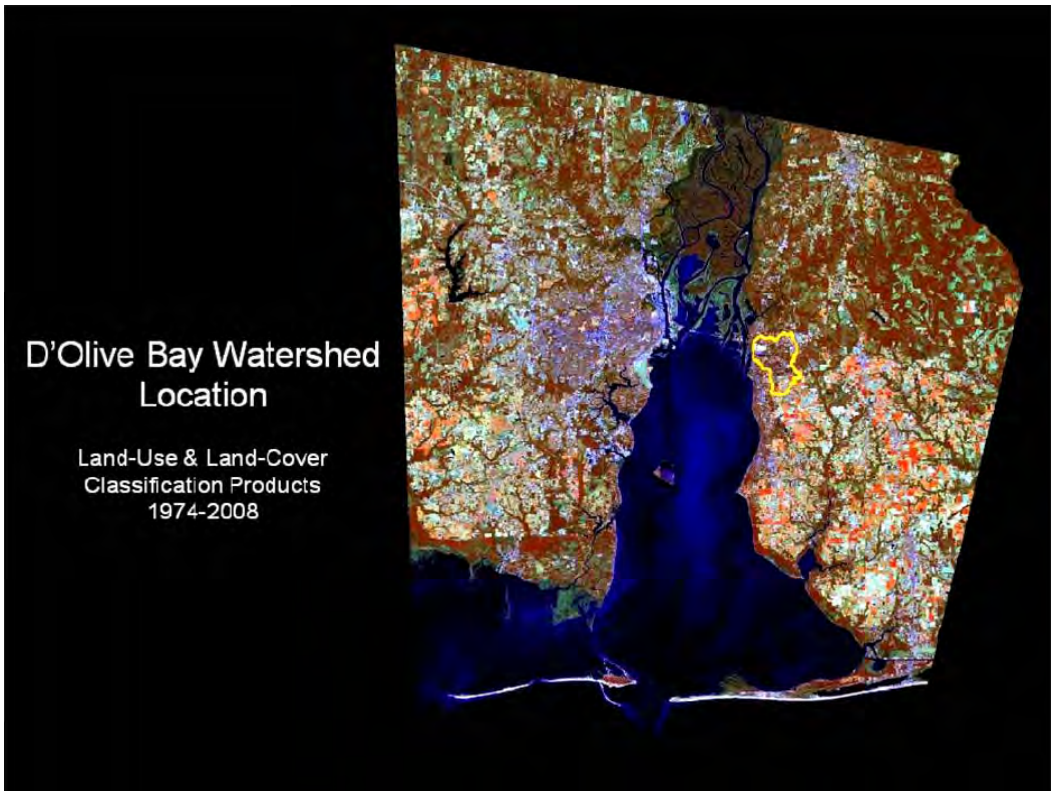
Landsat Thematic Mapper Data
Acquired : 03/16/2008

USGS 30 Meter Elevation Model
Mobile & Baldwin Counties

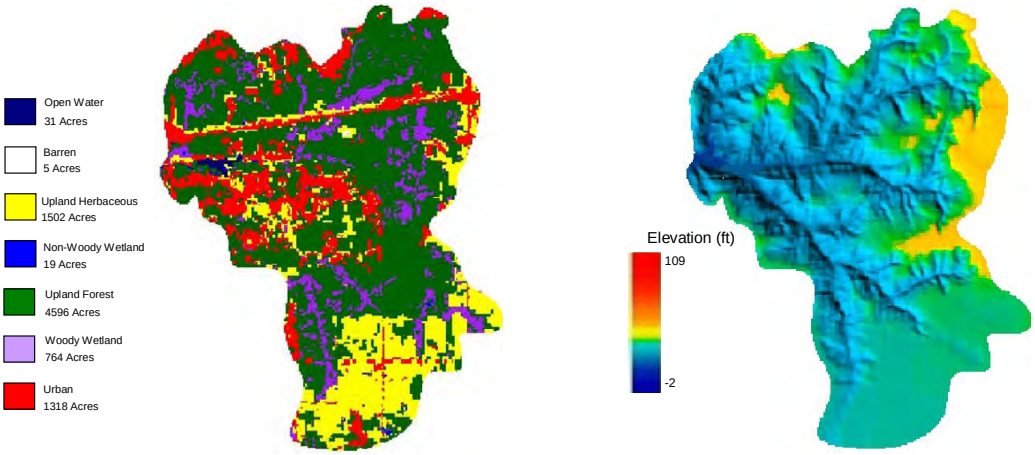



National Aeronautics and Space Administration
NASA Gulf of Mexico Initiative
NASA
Appendix II:
Watershed-scale Analysis


National Aeronautics and Space Administration
NASA Gulf of Mexico Initiative
NASA
D'Olive Bay


D'Olive Bay Watershed Location
Land-Use & Land-Cover Classification Products 1974-2008

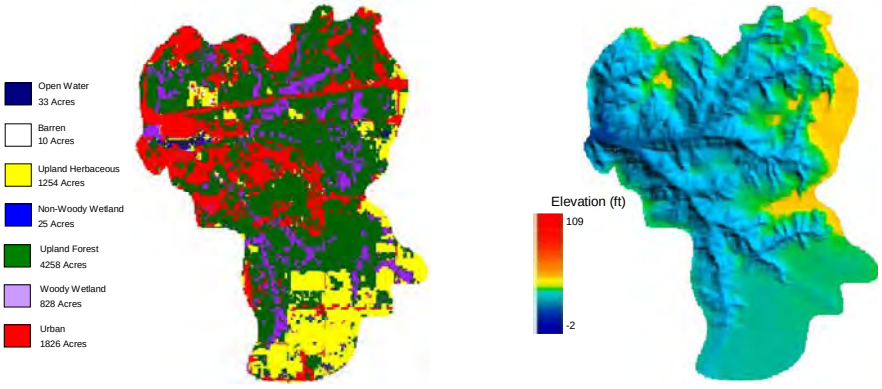
D'Olive Bay Watershed – 1974 Land-Use & Land-Cover Classification



Landsat Multispectral Scanner Data
Acquired: 11/12/1974

USGS Digital Elevation Model
30 Meter Resolution

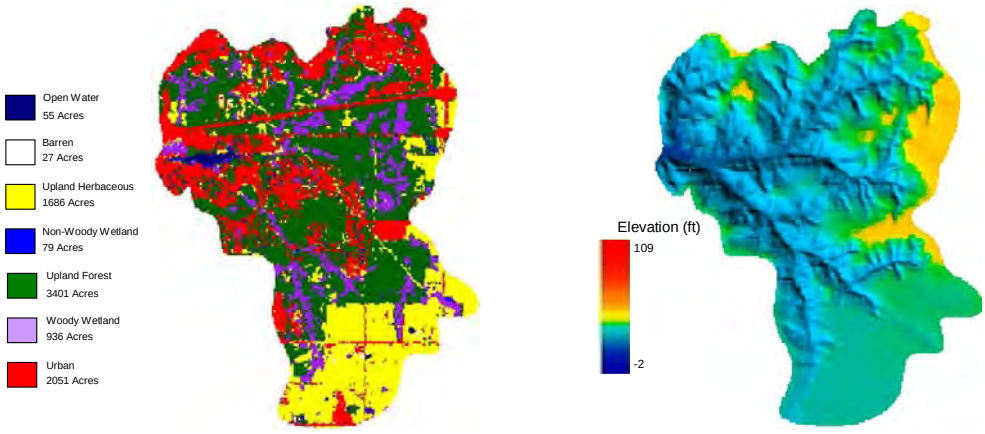
D'Olive Bay Watershed – 1984 Land-Use & Land-Cover Classification



Landsat Multispectral Scanner Data
Acquired: 09/06/1984

USGS Digital Elevation Model
30 Meter Resolution

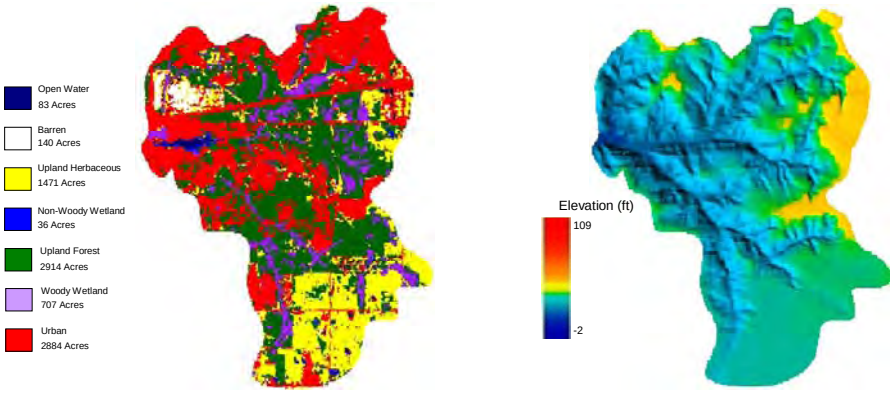
D'Olive Bay Watershed – 1996 Land-Use & Land-Cover Classification



Landsat Thematic Mapper Data
Acquired: 01/27/1996

USGS Digital Elevation Model
30 Meter Resolution

D'Olive Bay Watershed – 2008 Land-Use & Land-Cover Classification

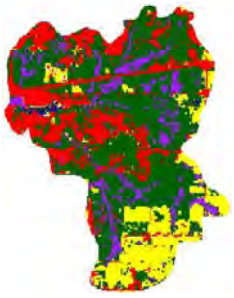


Landsat Thematic Mapper Data
Acquired: 03/16/2008

USGS Digital Elevation Model
30 Meter Resolution

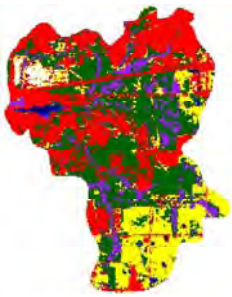
D'Olive Bay Watershed Land-Use & Land-Cover: Decadal Change

Landsat Multispectral Scanner
Acquired: 11/12/1974



Landsat Multispectral Scanner
Acquired: 09/06/1984

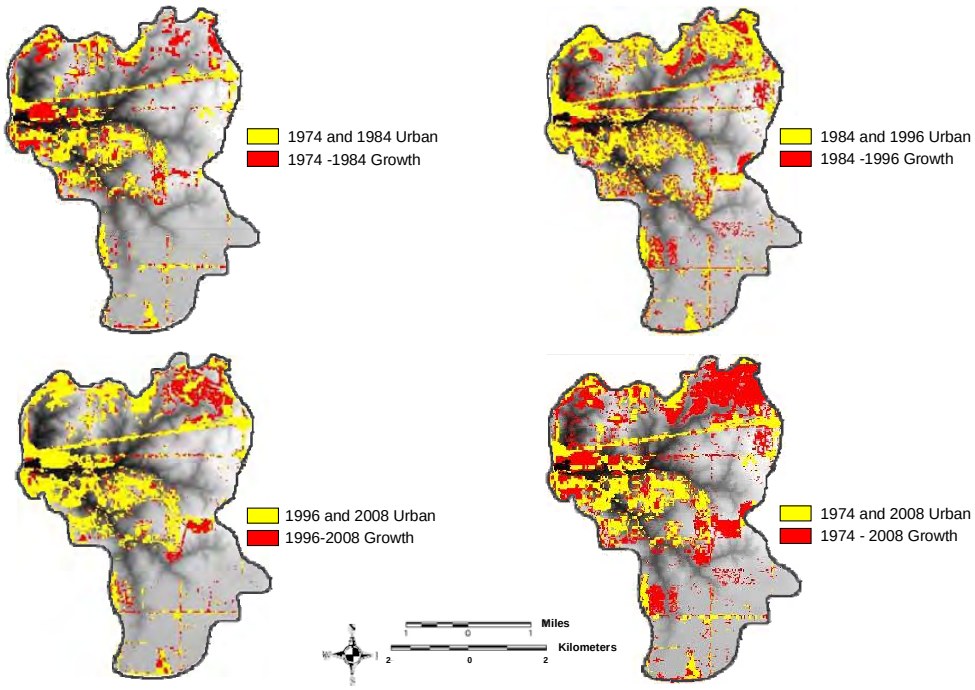
Landsat Thematic Mapper
Acquired: 01/27/1996



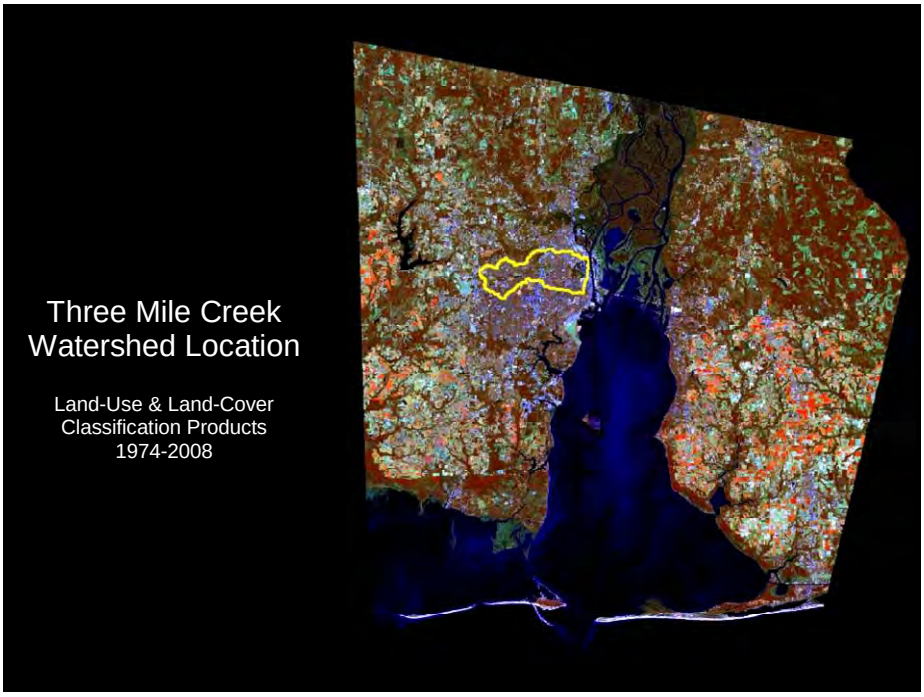
Landsat Thematic Mapper
Acquired: 03/16/2008

		1974		1984		1996		2008	
	Class Name	Total Acres	Percent	Total Acres	Percent	Total Acres	Percent	Total Acres	Percent
	Open Water	30.91	0.4	33.32	0.4	55.40	0.7	83.09	1.0
	Barren	5.22	0.1	10.24	0.1	26.69	0.3	140.10	1.7
	Upland Herbaceous	1501.92	18.2	1254.04	15.2	1685.97	20.5	1471.01	17.9
	Non-Woody Wetland	19.47	0.2	25.09	0.3	79.48	1.0	35.53	0.4
	Upland Forest	4596.08	55.8	4258.28	51.7	3400.85	41.3	2914.12	35.4
	Woody Wetland	763.71	9.3	828.13	10.1	935.71	11.4	707.10	8.6
	Urban	1317.87	16.0	1826.07	22.2	2051.07	24.9	2884.22	35.0
	Total	8235	100.0	8235	100.0	8235	100.0	8235	100.0

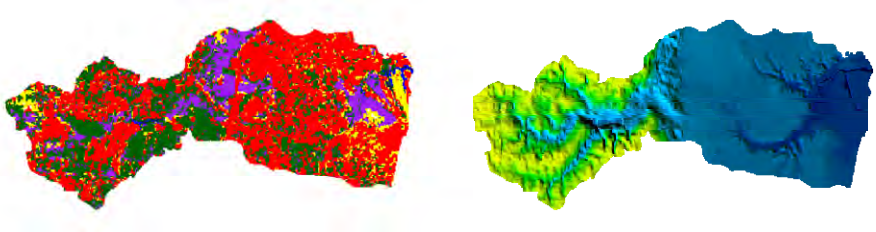
D'Olive Bay Watershed Urban Expansion Change Products: Decadal Comparisons




National Aeronautics and Space Administration
NASA Gulf of Mexico Initiative
NASA
Three Mile Creek

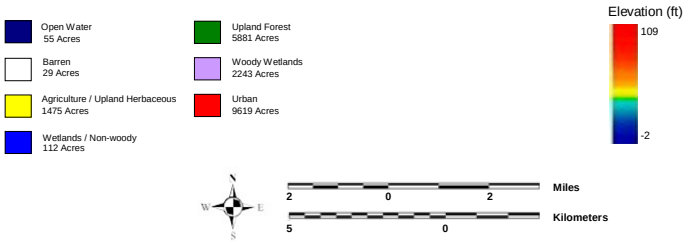

Three Mile Creek
Watershed Location
Land-Use & Land-Cover
Classification Products
1974-2008

Three Mile Creek Watershed – 1974 Land-Use & Land-Cover Classification

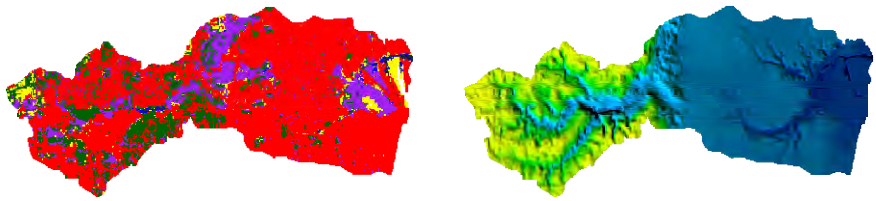


Landsat Multispectral Scanner Data
Date: 11/12/1974

USGS Digital Elevation Model
30 Meter Resolution

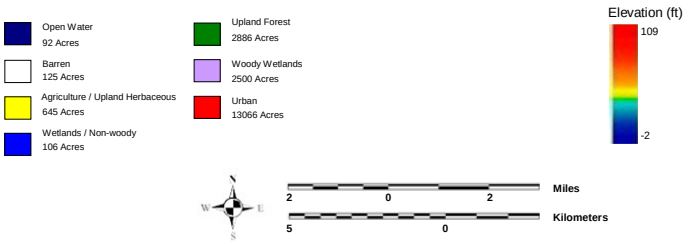


Three Mile Creek Watershed – 1984 Land-Use & Land-Cover Classification

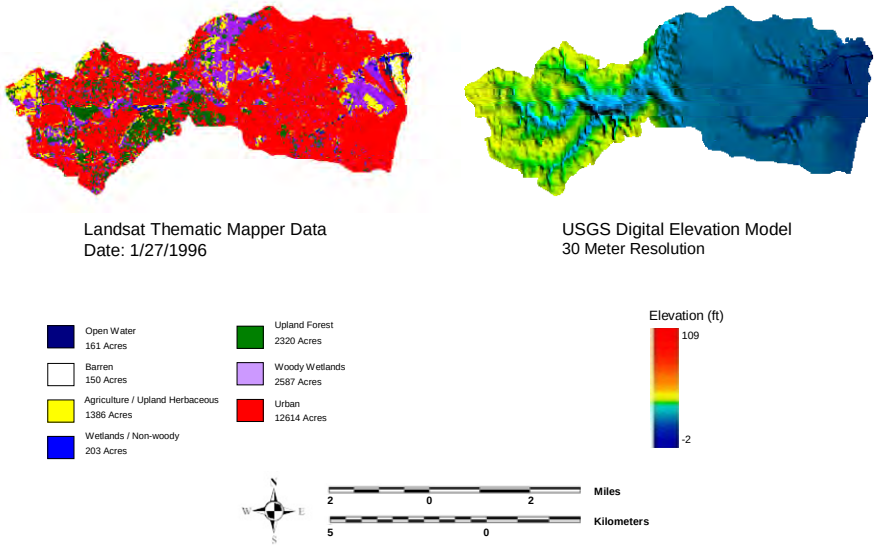


Landsat Multispectral Scanner Data
Date: 9/6/1984

USGS Digital Elevation Model
30 Meter Resolution



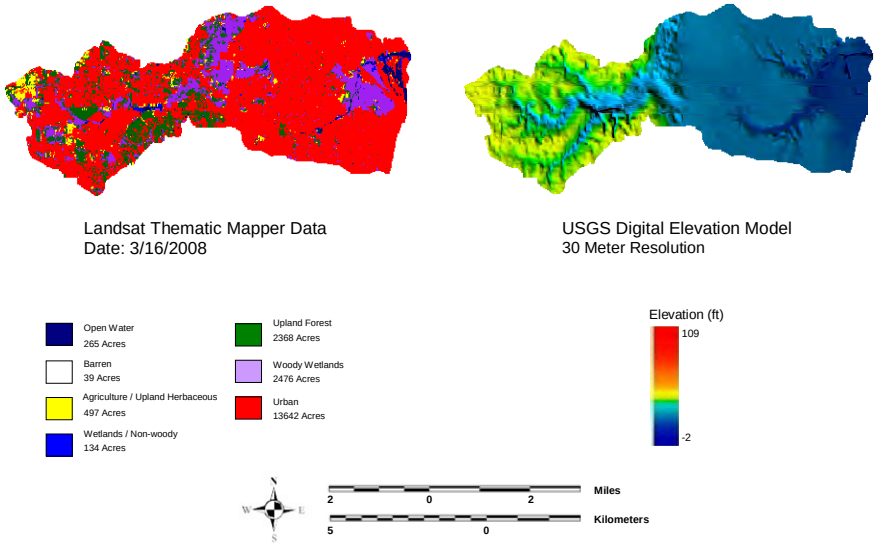
Three Mile Creek Watershed – 1996 Land-Use & Land-Cover Classification



Landsat Thematic Mapper Data
Date: 1/27/1996

USGS Digital Elevation Model
30 Meter Resolution

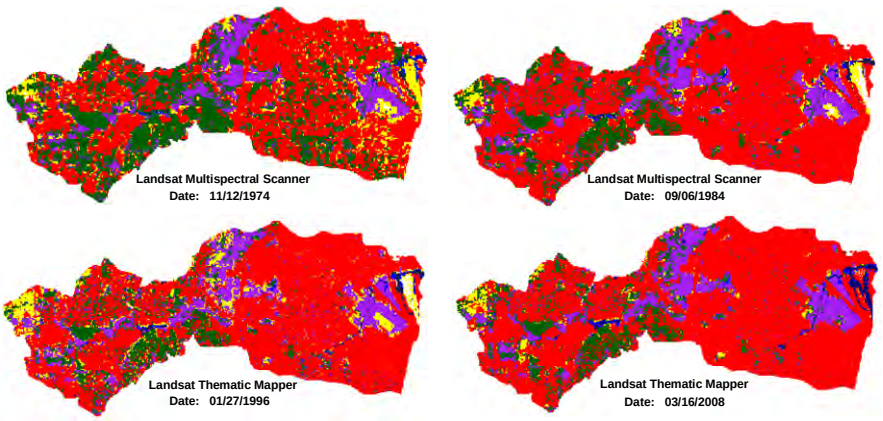
Three Mile Creek Watershed – 2008 Land-Use & Land-Cover Classification



Landsat Thematic Mapper Data
Date: 3/16/2008

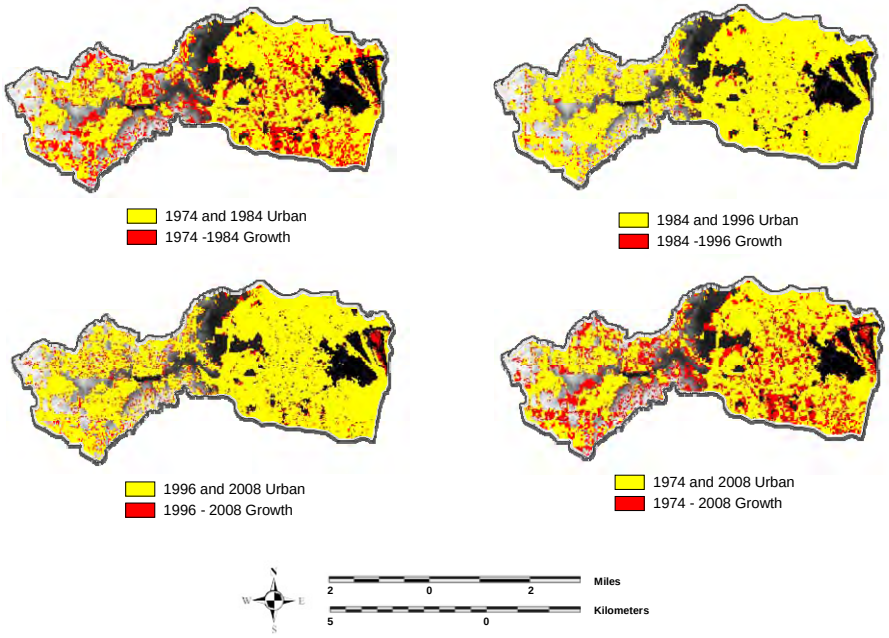
USGS Digital Elevation Model
30 Meter Resolution

Three Mile Creek Watershed Land-Use & Land-Cover: Decadal Change



		1974		1984		1996		2008	
	Class Name	Total Acres	Percent	Total Acres	Percent	Total Acres	Percent	Total Acres	Percent
	Open water	55	0.3	92	0.5	161	0.8	265	1.4
	Barren	29	0.2	125	0.6	150	0.8	39	0.2
	Agriculture	1475	7.6	645	3.3	1386	7.1	497	2.6
	Wetland non-woody	112	0.6	106	0.5	203	1.0	134	0.7
	Upland forest	5881	30.3	2886	14.9	2320	11.9	2368	12.2
	Wetland woody	2243	11.6	2500	12.9	2587	13.3	2476	12.8
	Urban	9619	49.5	13066	67.3	12614	65.0	13642	70.2
	Total	19415	100.0	19420	100.0	19420	100.0	19420	100.0

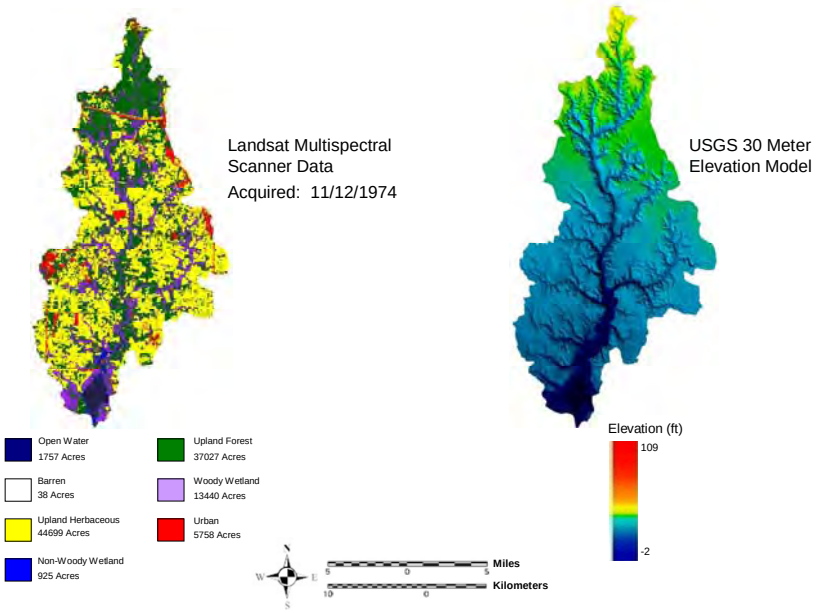
Three Mile Creek Watershed Urban Expansion Products: Decadal Comparisons



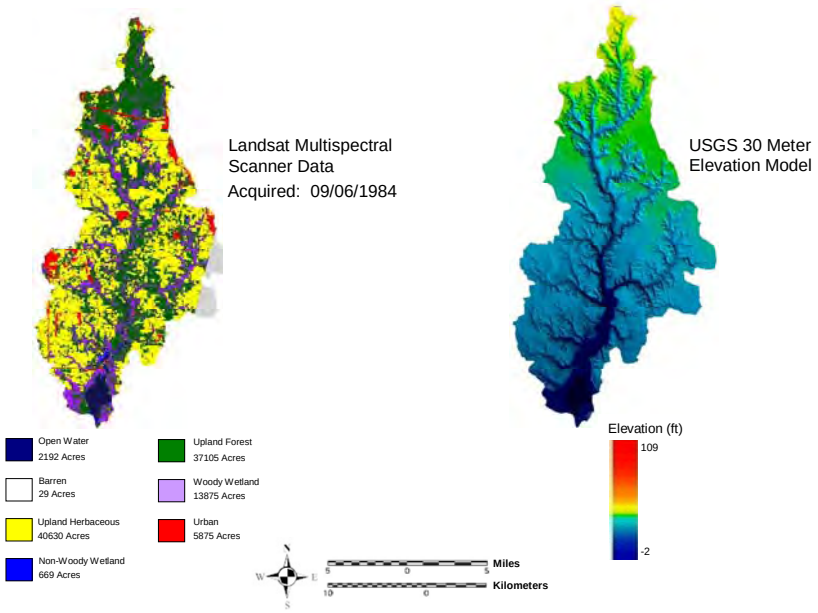

National Aeronautics and Space Administration
NASA Gulf of Mexico Initiative
NASA
Fish River


Fish River Watershed Location
Land-Use & Land-Cover Classification Products 1974-2008

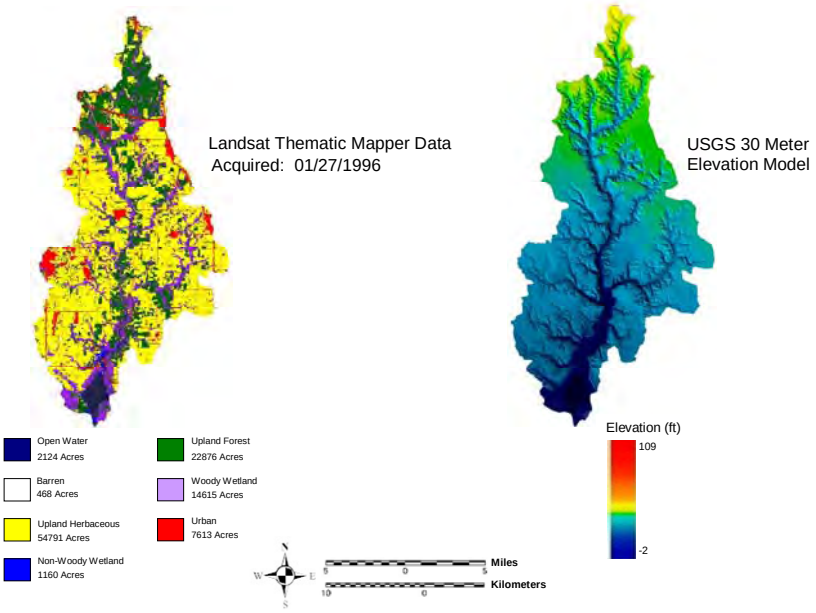
Fish River Watershed – 1974 Land-Use & Land-Cover Classification



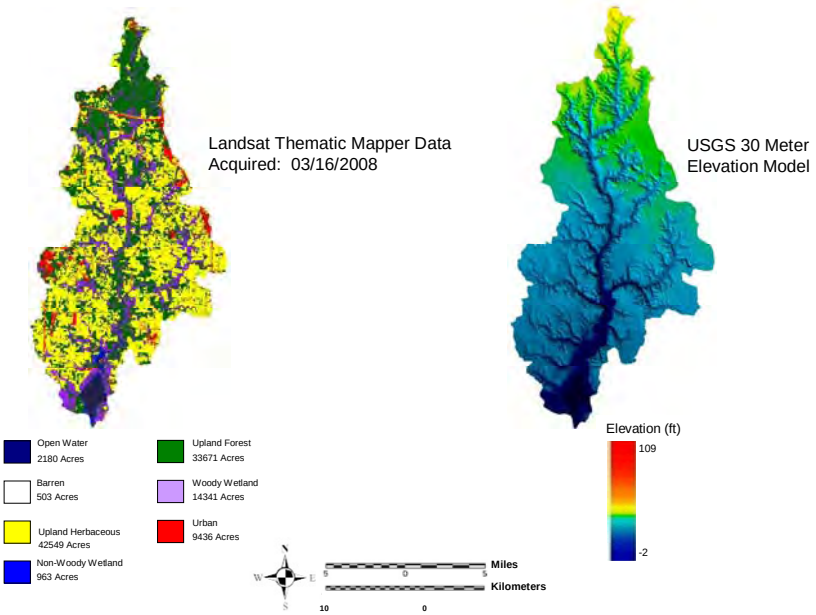
Fish River Watershed – 1984 Land-Use & Land-Cover Classification



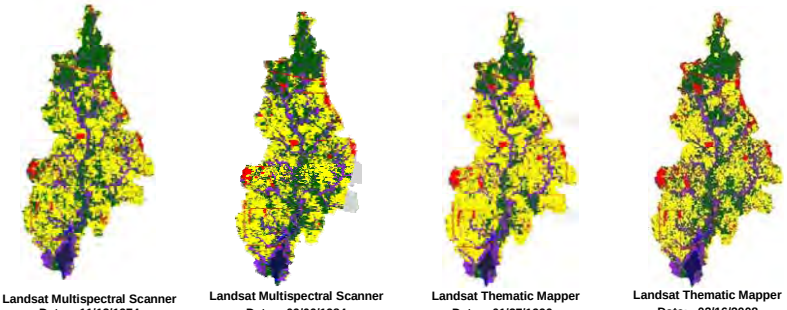
Fish River Watershed – 1996 Land-Use & Land-Cover Classification



Fish River Watershed – 2008 Land-Use & Land-Cover Classification

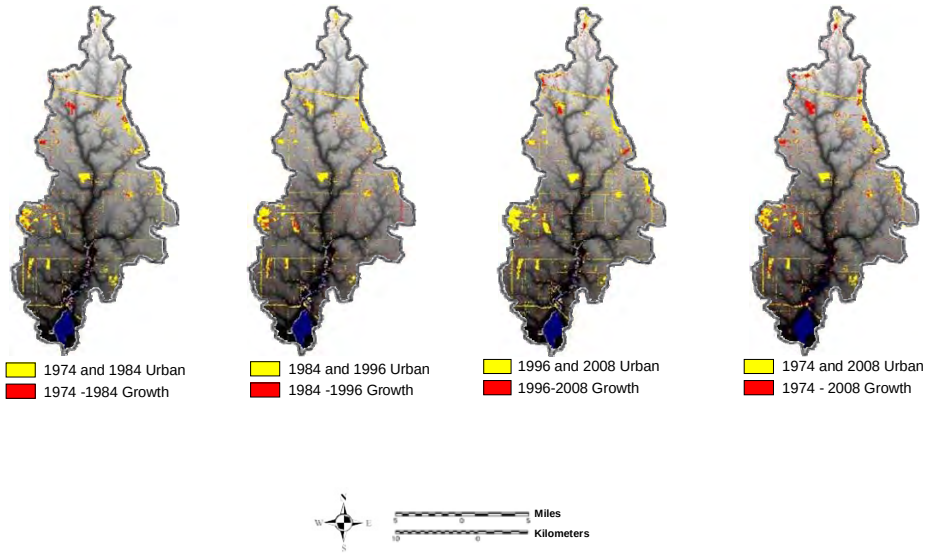


Fish River Watershed – Land-Use & Land-Cover: Decadal Change

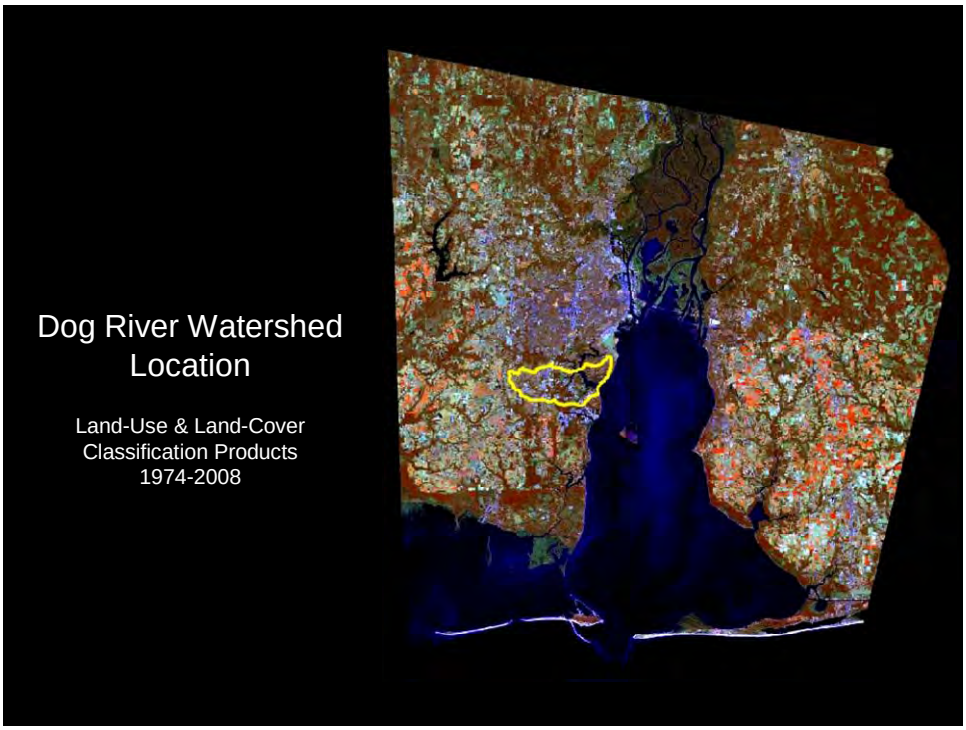


		1974		1984		1996		2008	
	Class Name	Total Acres	Percent	Total Acres	Percent	Total Acres	Percent	Total Acres	Percent
	Open water	1757	1.7	2192	2.2	2124	2.0	2183	2.1
	Barren	38	0.0	29	0.0	468	0.5	503	0.5
	Upland Herbaceous	44699	43.1	40630	40.5	54792	52.9	42603	41.1
	Non-Woody Wetland	925	0.9	669	0.7	1160	1.1	966	0.9
	Upland forest	37027	35.7	37105	37.0	22876	22.1	33641	32.5
	Woody Wetland	13440	13.0	13875	13.8	14615	14.1	14348	13.8
	Urban	5758	5.6	5875	5.9	7613	7.3	9404	9.1
	Total	103643	100.0	100373	100.0	103649	100.0	103649	100.0

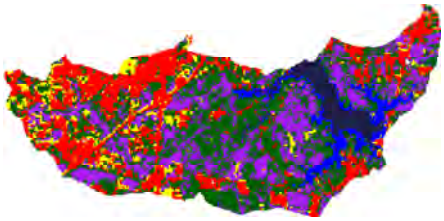
Fish River Watershed – Urban Expansion Change Products: Decadal Comparisons



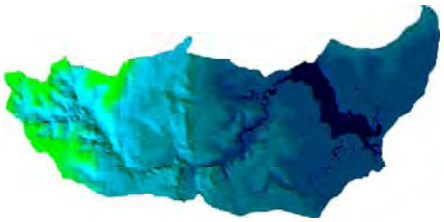

National Aeronautics and Space Administration
NASA Gulf of Mexico Initiative
NASA
Dog River


Dog River Watershed Location
Land-Use & Land-Cover Classification Products 1974-2008

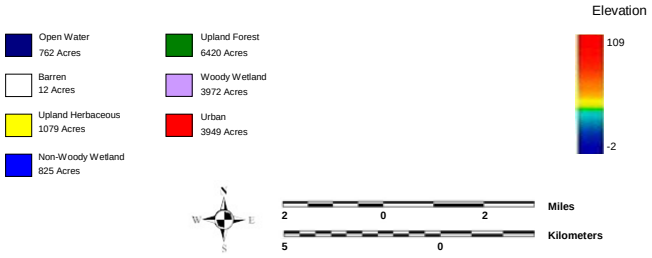
Dog River Watershed – 1974 Land Use Land Cover Classification



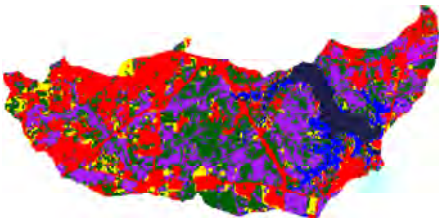
Landsat Multispectral Scanner Data
Acquired: 11/12/1974



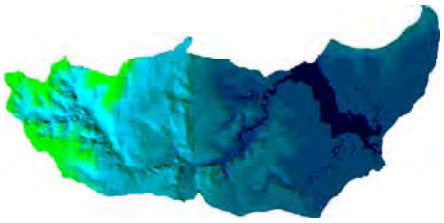
USGS Digital Elevation Model
30 Meter Resolution



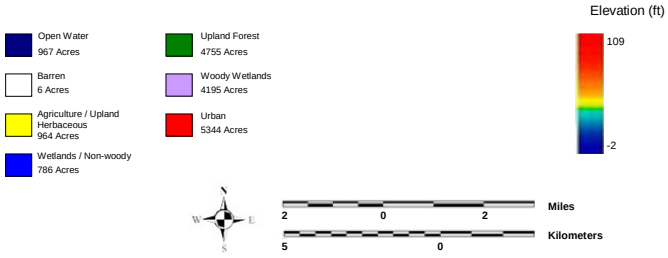
Dog River Watershed – 1984 Land Use Land Cover Classification



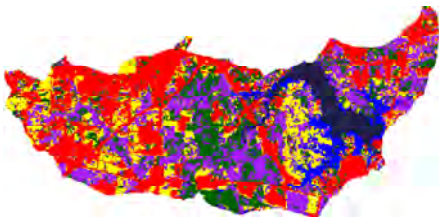
Landsat Multispectral Scanner Data
Acquired: 09/06/1984



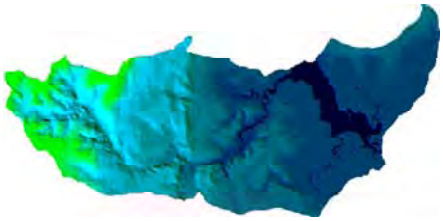
USGS Digital Elevation Model
30 Meter Resolution



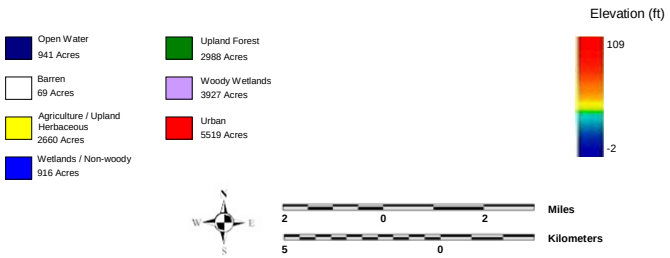
Dog River Watershed – 1996 Land Use Land Cover Classification



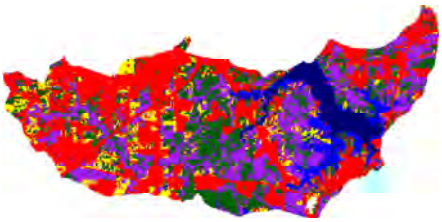
Landsat Thematic Mapper Data
Acquired: 01/27/1996



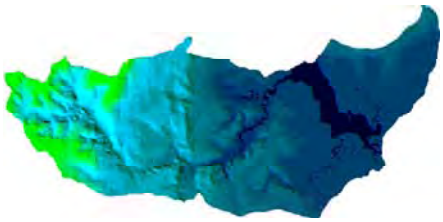
USGS Digital Elevation Model
30 Meter Resolution



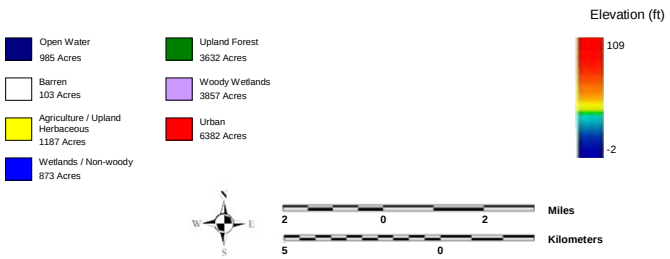
Dog River Watershed – 2008 Land-Use & Land-Cover Classification



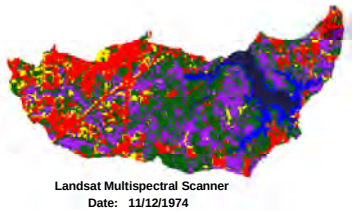
Landsat Thematic Mapper Data
Acquired: 03/16/2008



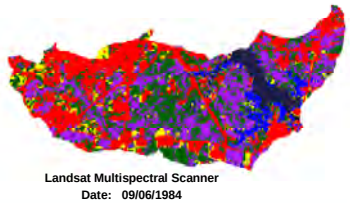
USGS Digital Elevation Model
30 Meter Resolution



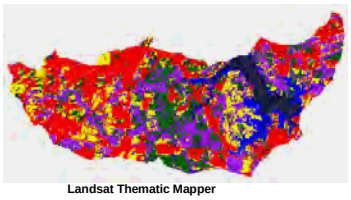
Dog River Watershed – Land-Use & Land-Cover: Decadal Change



Landsat Multispectral Scanner
Date: 11/12/1974



Landsat Multispectral Scanner
Date: 09/06/1984



Landsat Thematic Mapper
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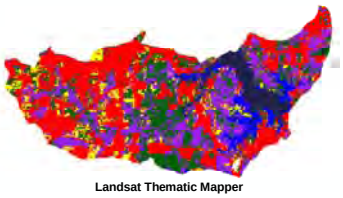

Landsat Thematic Mapper
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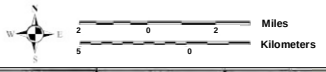
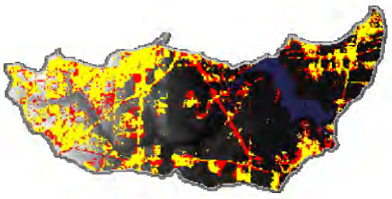
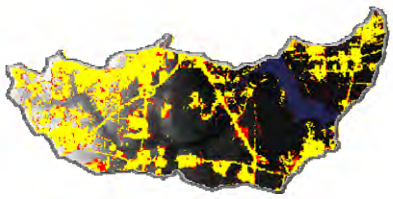


		1974		1984		1996		2008	
	Class Name	Total Acres	Percent	Total Acres	Percent	Total Acres	Percent	Total Acres	Percent
	Open water	762	4.5	967	5.7	941	5.5	985	5.8
	Barren	12	0.1	6	0.0	69	0.4	103	0.6
	Upland Herbaceous	1079	6.3	964	5.7	2660	15.6	1187	7.0
	Non-Woody Wetland	825	4.8	786	4.6	916	5.4	873	5.1
	Upland forest	6420	37.7	4755	27.9	2988	17.6	3632	21.3
	Woody Wetland	3972	23.3	4195	24.7	3927	23.1	3857	22.7
	Urban	3949	23.2	5344	31.4	5519	32.4	6382	37.5
	Total	17018	100.0	17019	100.0	17019	100.0	17019	100.0

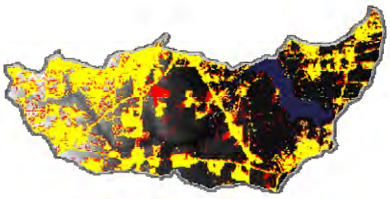
Dog River Watershed – Urban Expansion Change Products: Decadal Comparisons



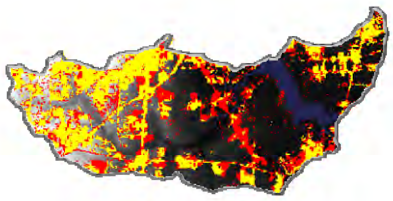
1974 and 1984 Urban
1974 -1984 Growth



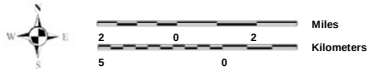
1984 and 1996 Urban
1984 -1996 Growth



1996 and 2008 Urban
1996-2008 Growth



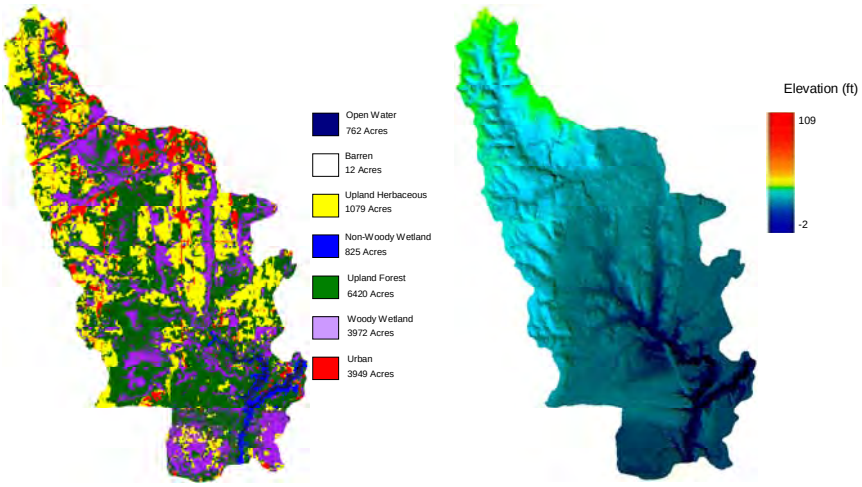
1974 and 2008 Urban
1974 - 2008 Growth




National Aeronautics and Space Administration
NASA Gulf of Mexico Initiative
NASA
Fowl River

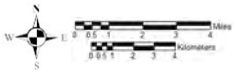

Fowl River Watershed Location
Land-Use & Land-Cover Classification Products 1974-2008

Fowl River Watershed – 1974 Land-Use & Land-Cover Classification

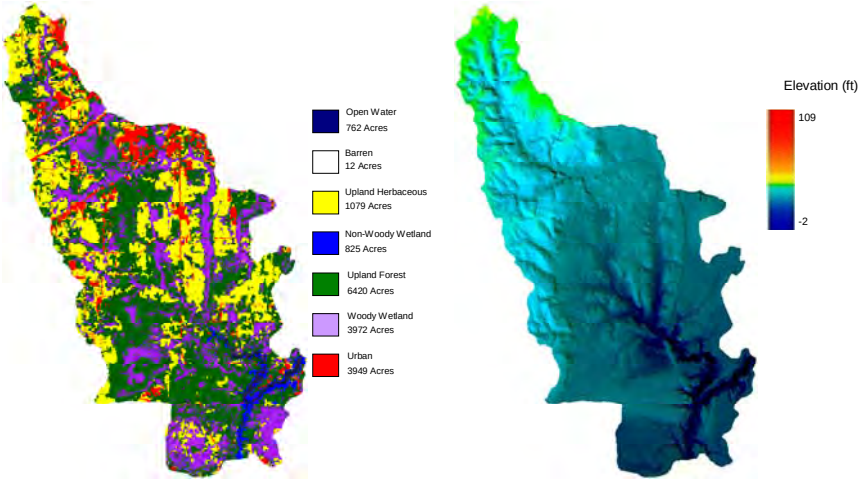


Landsat Multispectral Scanner Data
Acquired: 11/12/1974

USGS Digital Elevation Model
30 Meter Resolution

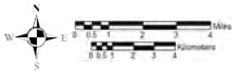


Fowl River Watershed – 1984 Land-Use & Land-Cover Classification

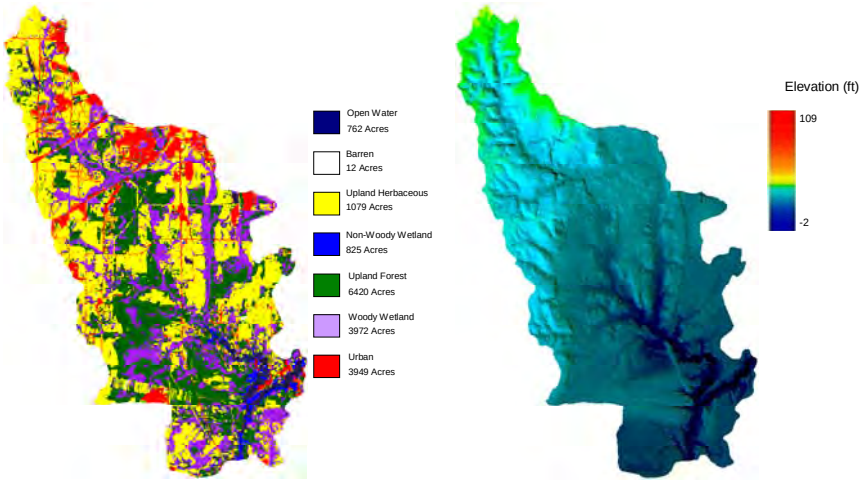


Landsat Multispectral Scanner Data
Acquired: 09/06/1984

USGS Digital Elevation Model
30 Meter Resolution

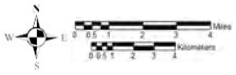


Fowl River Watershed – 1996 Land-Use & Land-Cover Classification

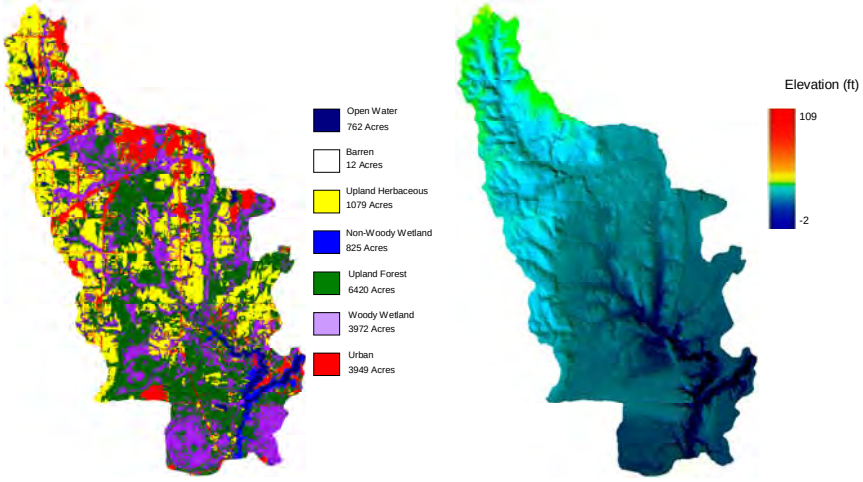


Landsat Thematic Mapper Data
Acquired: 01/27/1996

USGS Digital Elevation Model
30 Meter Resolution

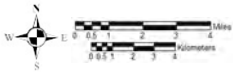


Fowl River Watershed – 2008 Land-Use & Land-Cover Classification

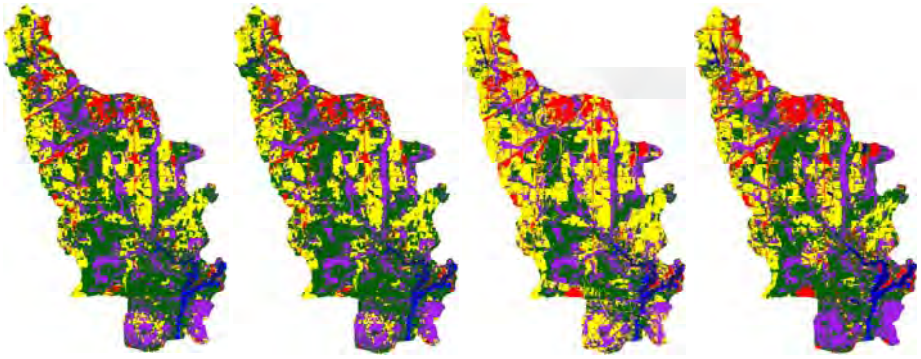


Landsat Thematic Mapper Data
Acquired: 03/16/2008

USGS Digital Elevation Model
30 Meter Resolution



Fowl River Watershed – Land-Use & Land-Cover: Decadal Change



Landsat Multispectral Scanner
Date: 11/12/1974

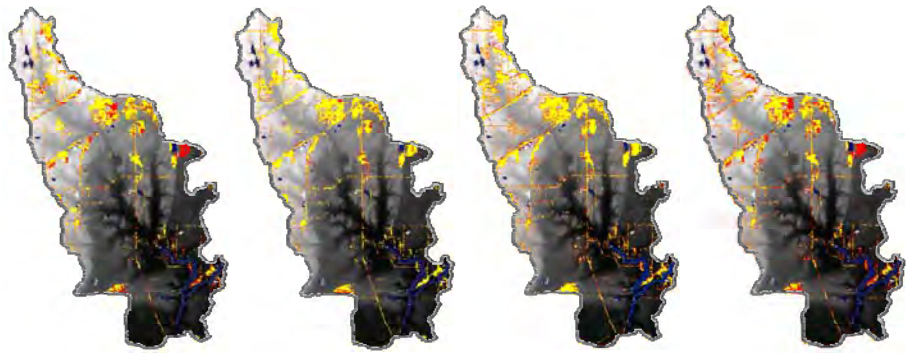
Landsat Multispectral Scanner
Date: 09/06/1984

Landsat Thematic Mapper
Date: 01/27/1996

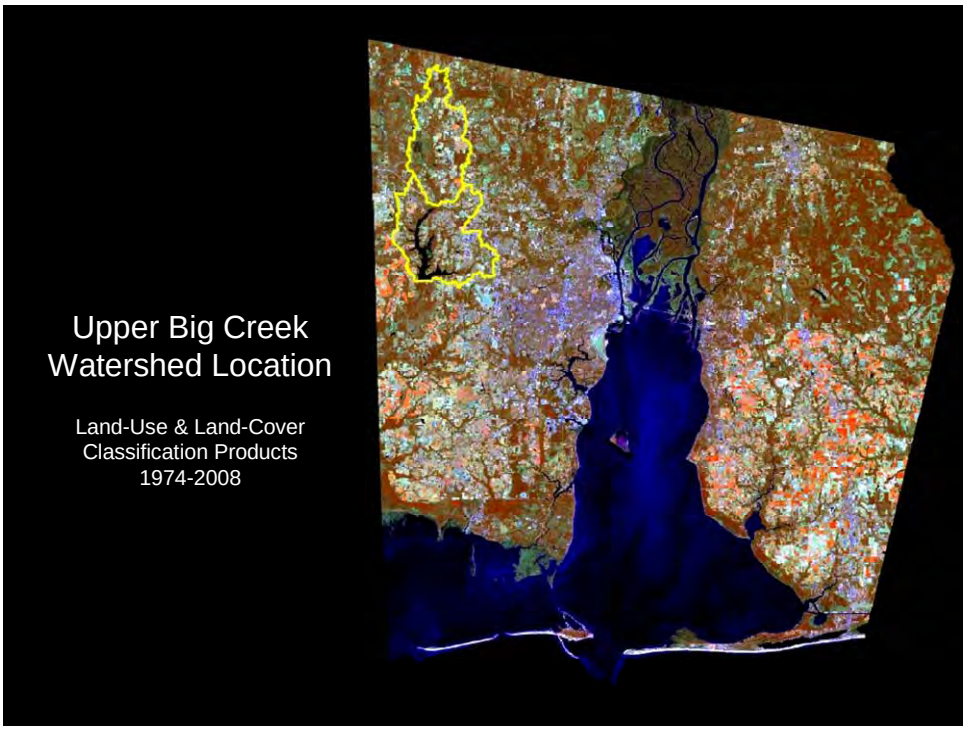
Landsat Thematic Mapper
Date: 03/16/2008

		1974		1984		1996		2008	
	Class Name	Total Acres	Percent	Total Acres	Percent	Total Acres	Percent	Total Acres	Percent
	Open water	461	1.1	660	1.6	741	1.8	790	2.0
	Barren	3	0.0	43	0.1	150	0.4	99	0.2
	Upland Herbaceous	10093	25.1	7847	19.5	15093	37.6	9921	24.7
	Non-Woody Wetland	654	1.6	625	1.6	765	1.9	686	1.7
	Upland forest	17576	43.7	18150	45.2	11028	27.4	14888	37.1
	Woody Wetland	8368	20.8	9142	22.7	8270	20.6	8947	22.3
	Urban	3028	7.5	3717	9.3	4136	10.3	4850	12.1
	Total	40182	100.0	40184	100.0	40184	100.0	40180	100.0

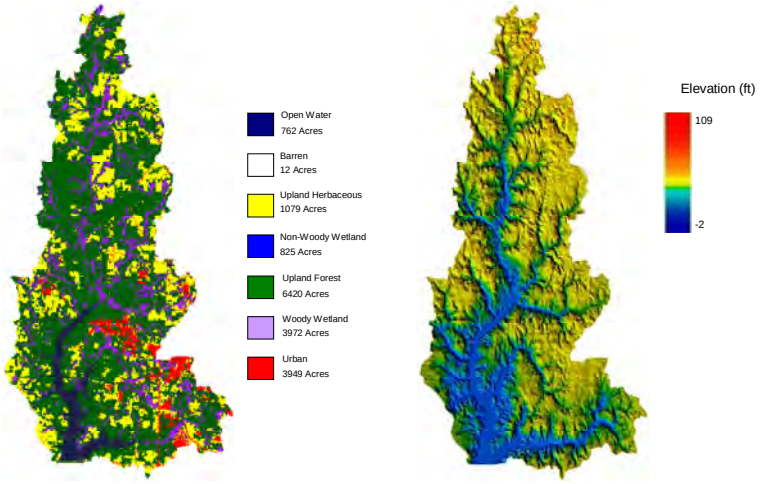
Fowl River Watershed – Urban Expansion Change Products: Decadal Comparisons




National Aeronautics and Space Administration
NASA Gulf of Mexico Initiative
NASA
Upper Big Creek

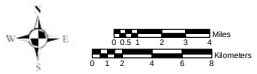

Upper Big Creek
Watershed Location
Land-Use & Land-Cover
Classification Products
1974-2008

Upper Big Creek Watershed – 1974 Land-Use & Land-Cover Classification

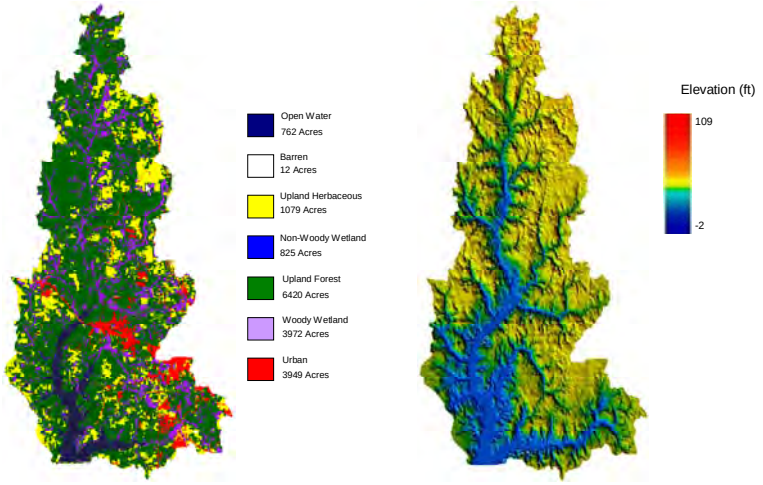


Landsat Multispectral Scanner Data
Acquired: 11/12/1974

USGS Digital Elevation Model
30 Meter Resolution

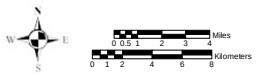


Upper Big Creek Watershed – 1984 Land-Use & Land-Cover Classification

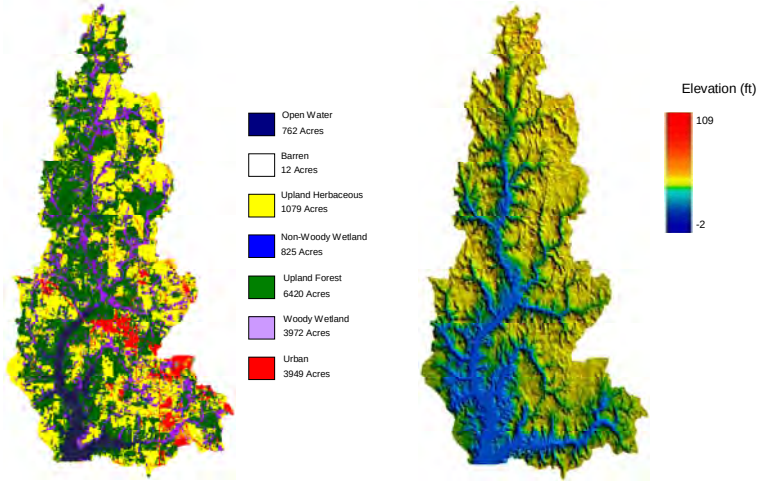


Landsat Multispectral Scanner Data
Acquired: 09/06/1984

USGS Digital Elevation Model
30 Meter Resolution

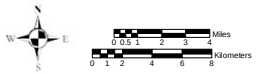


Upper Big Creek Watershed – 1996 Land-Use & Land-Cover Classification

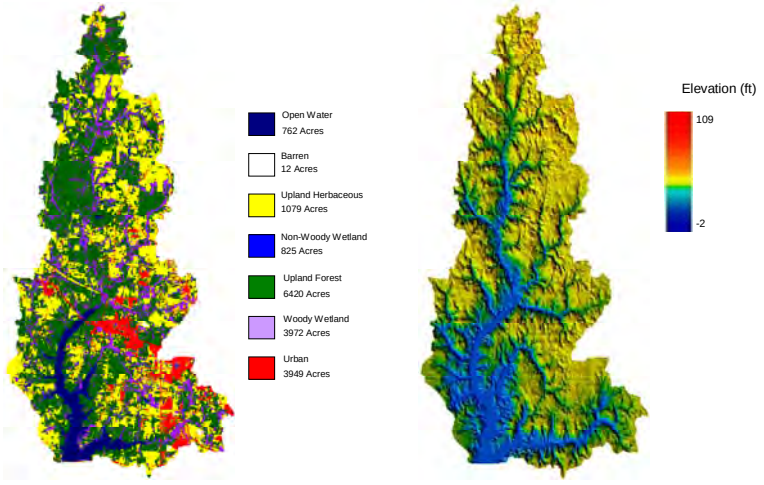


Landsat Thematic Mapper Data
Acquired: 01/27/1996

USGS Digital Elevation Model
30 Meter Resolution

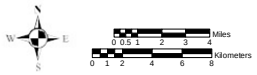


Upper Big Creek Watershed – 2008 Land-Use & Land-Cover Classification

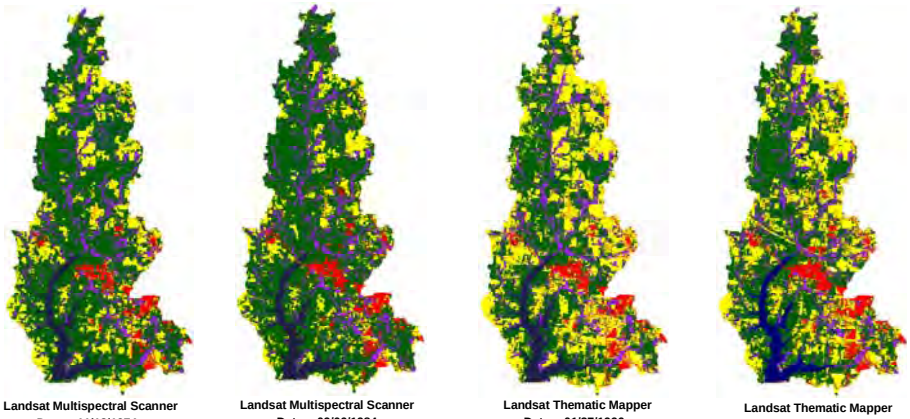


Landsat Thematic Mapper Data
Acquired: 03/16/2008

USGS Digital Elevation Model
30 Meter Resolution



Upper Big Creek Watershed Land-Use & Land-Cover: Decadal Change



Landsat Multispectral Scanner
Date: 11/12/1974

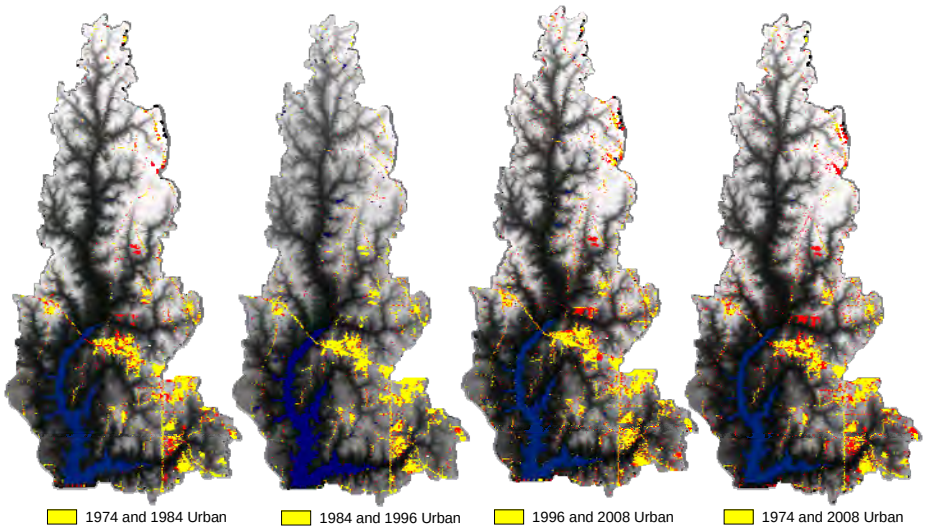
Landsat Multispectral Scanner
Date: 09/06/1984

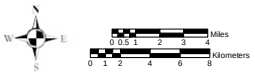
Landsat Thematic Mapper
Date: 01/27/1996

Landsat Thematic Mapper
Date: 03/16/2008

		1974		1984		1996		2008	
	Class Name	Total Acres	Percent	Total Acres	Percent	Total Acres	Percent	Total Acres	Percent
	Open water	2990	4.5	3599	5.4	3517	5.2	3515	5.2
	Barren	17	0.0	26	0.0	110	0.2	153	0.2
	Upland Herbaceous	13402	20.0	9841	14.7	22349	33.3	18347	27.4
	Non-Woody Wetland	120	0.2	176	0.3	354	0.5	327	0.5
	Upland forest	39566	59.0	41456	61.8	28394	42.3	31709	47.3
	Woody Wetland	7849	11.7	8268	12.3	8477	12.6	7863	11.7
	Urban	3104	4.6	3685	5.5	3851	5.7	5137	7.7
	Total	67048	100.0	67051	100.0	67051	100.0	67051	100.0

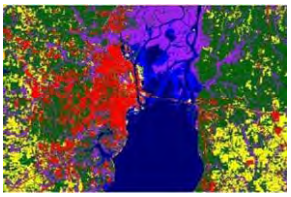
Upper Big Creek Watershed – Urban Expansion Products: Decadal Comparisons





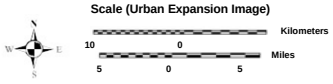
Northern Mobile Bay Land-Use & Land-Cover: Decadal Change

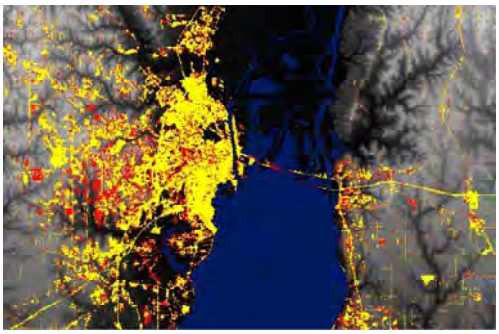
1974 versus 1984 Urban Expansion



1974 Land-Use & Land-Cover Classification
Date: 11/12/1974

1984 Land-Use & Land-Cover Classification
Date: 09/06/1984



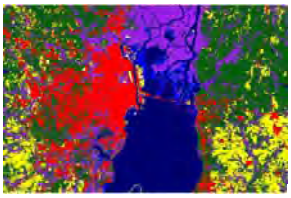


1974 and 1984 Urban 1974 -1984 Growth

Class	1974 Total Acres	1974 Percent	1984 Total Acres	1984 Percent
Open water	82248	16.2	88978	17.5
Barren	709	0.1	1059	0.2
Upland Herbaceous	67774	13.3	60179	11.8
Wetland/non-woody	20409	4.0	13572	2.7
Upland forest	189699	37.3	174052	34.2
Wetland/woody	86295	17.0	89819	17.6
Urban	61949	12.2	81358	16.0
Total	509084	100.0	509016	100.0

Northern Mobile Bay Land-Use & Land-Cover: Decadal Change

1984 versus 1996 Urban Expansion



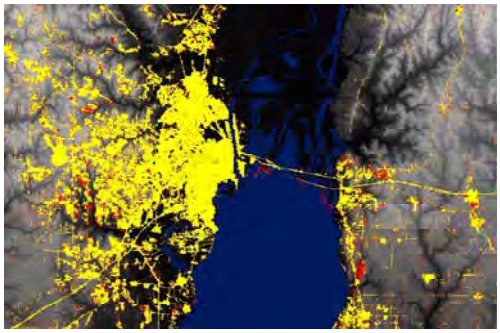
1984 Land-Use & Land-Cover Classification
Date: 09/06/1984

1996 Land-Use & Land-Cover Classification
Date: 01/27/1996

Scale (Urban Expansion Image)

Kilometers 10 0

Miles 5 0 5



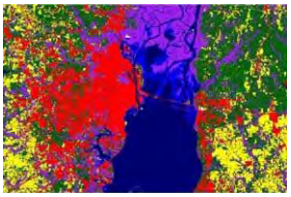
1974 and 1996 Urban 1984 -1996 Growth

Class	1984 Total Acres	1984 Percent	1996 Total Acres	1996 Percent
Open water	88978	17.5	87405	17.2
Barren	1059	0.2	1639	0.3
Upland Herbaceous	60179	11.8	105111	20.6
Wetland non-woody	13572	2.7	17447	3.4
Upland forest	174052	34.2	120339	23.6
Wetland woody	89819	17.6	92689	18.2
Urban	81358	16.0	84404	16.6
Total	509016	100.0	509035	100.0

Northern Mobile Bay Land-Use & Land-Cover: Decadal Change

1996 versus 2008 Urban Expansion

1996 Land-Use & Land-Cover Classification
Date: 01/27/1996

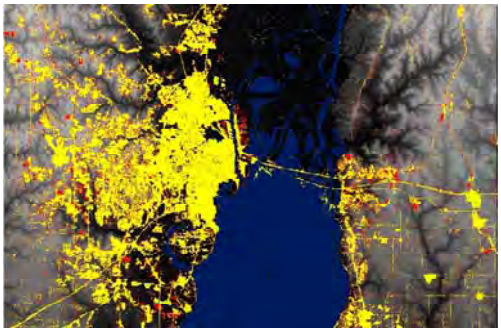


2008 Land-Use & Land Cover Classification
Date: 03/16/2008

Scale (Urban Expansion Image)

Kilometers 10 0

Miles 5 0 5



1996 and 2008 Urban 1996 -2008 Growth

Class	1996 Total Acres	1996 Percent	2008 Total Acres	2008 Percent
Open water	87405	17.2	89556	17.6
Barren	1639	0.3	1731	0.3
Upland Herbaceous	105111	20.6	71628	14.1
Wetland non-woody	17447	3.4	17111	3.4
Upland forest	120339	23.6	142146	27.9
Wetland woody	92689	18.2	88729	17.4
Urban	84404	16.6	98037	19.3
Total	509035	100.0	508939	100.0

Northern Mobile Bay - Decadal Comparisons of Urban Expansion